TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XXVI Nos. 7–12 JULY — DECEMBER 1949 PRICE 3/-

CONTENTS

	PAGE
Agricultural Extension Work in the Colonies	70– 75
Review: Five Hundred Varieties of Herbage and Fodder Plants	75
Obituary: Sir Frank Stockdale, G.C.M.G., C.B.E., M.A., F.L.S.	76
Obituary: Sir Norman Lamont (Bart.)	77
Banana Research at I.C.T.A.	78– 84
Phosphate Deficiency in some West Indian Soils as Revealed by Pot Tests	85– 92
Some Recent Developments in Froghopper Control	93–102
Notes on the Grazing Lands of British Guiana	103–106
Review: Growth Substances and their Practical Importance in Horticulture	106–107
A Note on Nitrate Accumulation in a Uganda Soil	108–110
Further Observations on the "Unknown Disease" of Coconuts	110–112
A Further Investigation in the Control of the Trinidad Froghopper	113–117
Vesicular-Arbuscular Mycorrhiza in Sea Island Cotton and other Tropical Plants	118–121
The Use of Dynamite in Lifting Bamboo Clumps for Propagation	122–123
A Simple Mathematical Procedure for Use in Curing Vanilla to a Desired Moisture Content	124–125
Some Books on Tropical Agriculture Published on the Continent of Europe during and since the War	126–128
Manurial Experiments with Papaw *(Carica Papaya)*	129–132
Review: Bananas	132
The Occurrence of Phases in Insects other than Locusts	133–135
Initial Success of Attempts at the Biological Control of the Weed *Cordia Macrostachya* (Jacq.) R. & S. in Mauritius	135–136

TROPICAL AGRICULTURE is published by the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, 40, Norfolk Street, Strand, London, W.C. 2, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

Cables: "Stomata."

'Phone: St. Augustine 94241

EDITORIAL NOTE

With this issue of "Tropical Agriculture", completing Volume 26 we have caught up on the serious arrears in publication occasioned by post-war printing difficulties. We apologise to contributors whose communications have been seriously held up, but hope that in future all material accepted for publication will be published promptly.

In 1950 Tropical Agriculture will be published quarterly. The possible later resumption of monthly publication will depend on the amount of material available for publication and on the stabilisation of the new editorial and printing arrangements. Certain changes in make up and content are contemplated. These will be announced in the first number of the next volume.

H. J. P.

AGRICULTURAL EXTENSION WORK IN THE COLONIES

*The Report entitled "Agricultural Extension and Advisory Work with special reference to the Colonies" by Mr. C. W. Lynn, M.B.E. * is based on a study made in 1947 of extension and advisory work in England, Canada, U.S.A. and Puerto Rico, after eighteen years' experience as an agricultural officer in the Gold Coast.*

The following consists of abridged extracts from the Report, reprinted with acknowledgements to "The Colonial Review" †

Survival of the human race depends upon raising the efficiency of agricultural production throughout the world: this is the challenge presented to agricultural advisory and extension services. Governments in all countries are faced with problems of feeding and clothing growing populations in a world in which, with few exceptions, traditional farming methods, so far from maintaining soil fertility, have resulted in the destruction of the soil itself.

Increased attention to colonial welfare and rural betterment has stimulated interest in extension methods. Unfortunately there has been a tendency to adopt an urban approach; extension has been thought of in terms of stunts — radio, pictures and band waggons — isolated from the basic agricultural implications. There is no "ju-ju" about extension, there are no short cuts or magic wands, it is not an accessory which can be clipped on to a Department of Agriculture but an integral function of a department adequately staffed and orientated for the purpose. Impatience with the progress of extension work is leading some Colonies to consider the need for compulsion to speed up rural betterment. It cannot be denied that the situation has deteriorated in some places to such an extent that special measures have become necessary. Nevertheless, force and legislation offer no permanent solution for agricultural ills in the absence of a sound policy based on survey and research and an adequate organization for extension. It is significant that in Britain, where agricultural legislation is stricter than in any other democratic country in the world and agricultural research has been proceeding for over a century, a most comprehensive advisory service, the National Agricultural Advisory Service, has been introduced.

Agricultural extension is the term used to describe the complex of processes by which rural people are persuaded to adopt improved farming methods and improved ways of living. The success of an agricultural policy is measured in terms of its influence upon the lives and practices of rural people. The gap between the best scientific knowledge and current practice provides the field of scope for the extension worker, extension provides the bridge across the gap; it is a two-way bridge carrying information from the experiment station to the people, and bringing back knowledge based upon local experience, with further problems for investigation. Agricultural extension is essentially rural teaching. It differs from ordinary teaching in the school sense in that participation is purely voluntary, instruction is informal, the class-room is the field or barn, and the potential class is the total rural population. The aim of extension work in general is not to provide personal service, but to teach people what to do and how to do it for themselves. In practice, it is concerned also with the organization of rural people for rural betterment, and with the provision of related specialist services which individuals are unable to provide for themselves, such services for example as soil testing, livestock and crop improvement schemes, planning for soil conservation and so on.

The general aims of agricultural extension have been well expressed by the Director of Extension, New Mexico, as follows: (1) To contribute to the individual and collective welfare of rural people. (2) To help farm people to make adjustments to meet changing economic and social conditions and technological development. (3) To aid in the efficiency of production and distribution of food and fibre. (4) To aid in maintaining the productivity of the soil and in the wise use of water resources.

Extension presupposes knowledge to extend. Only proved results from experiments have a place in the extension programme and extension work must be supported by continuous research. In the U.S.A. and Britain agricultural research had been proceeding for nearly a century before national extension and advisory methods were developed. Most Colonies have only recently reached the stage when they have information to extend. Disappointment is often experienced in extension because problems have not been investigated in the order of their importance and important links are missing from the chain between the experiment station and the farmer. It

* Senior Lecturer in Agricultural Advisory and Extension Methods (now Acting Professor of Agriculture) at the I.C.T.A. (Colonial No. 241, 1949, pp. 104, 2s.)

† September, 1949.

is obviously not possible to investigate all rural problems before entering upon the extension phase, the secret is to take first things first as indicated by survey. Shortage of water in the Northern Territories of the Gold Coast was considered by the people to be of greater importance than the periodic shortage of food. The Department of Agriculture made little progress with its manuring extension policy until it had first won the people's confidence with a well-digging and pond-making programme. In backward countries people become so familiar with their problems that they tend to take them for granted; in such cases it may be necessary to convince the people of the problems by demonstrating the solutions before progress can be made. That the solution must be within the capacity of the best local farmers requires no emphasis, yet it is a point often overlooked particularly by specialists.

In all democratic countries the people participate in planning. In Britain half the Agricultural Improvement Council, which is responsible for guiding the National Advisory Service, is composed of farmers; County Executive Committees consist of farmers, farm workers and landowners' representatives; District Committees consist of farmers. In Canada, agricultural representatives act as secretaries to County Committees on which all farm organizations in the County are represented; the function of these committees is to survey the local situation and to develop plans. In the United States, County agents plan with community groups and country planning committees. The aim is to make the people feel that the extension programme is their own, which they are carrying out in co-operation with Government. In the Colonies we have not gone far enough yet with this idea. The development of agricultural extension services through the Native Administrations, or other forms of local government, is helpful, financed if necessary by subvention from the Central Government. Annual Native Administration estimates meetings become local extension planning committees when agricultural estimates are being discussed. The whole extension field is covered starting with a general statement of agricultural policy and progress; proceeding to a discussion of personal emoluments and travelling allowances for instructors and demonstrators, the expenditure on and revenue from demonstration farms, the provision of facilities for short courses, implement loan schemes, the supply of vegetable seeds, and so on. This way of working has given excellent results in Uganda, Nigeria and the Gold Coast, and has the effect of drawing-in the Administration closely with extension work to the success of which they have so much to contribute.

Extension workers cannot confine themselves effectively to a narrow interpretation of their duties, particularly in backward areas. All aspects of rural life must go forward together as part of one policy; it leads to frustration and stagnation when one aspect of policy is allowed to get out of step with another. The Tennessee Valley Authority provides a splendid example of integrated planning. The Taos County Project in New Mexico has a similar aim on a smaller scale. In the Colonies co-ordinated development plans are now being prepared. In East Africa, District and Provincial Welfare Teams, consisting of all the Government field officers in the area under the chairmanship of the administrator, help to unify outlook and policy; their development in West Africa is desirable. Gone, we hope, are the days when extension officers of an agricultural department advise farmers to conserve manure to increase soil fertility and extension officers in the medical department advise farmers to destroy manure because it breeds flies. Little wonder that the bewildered farmer does neither, and Governments complain of the stubbornness of the people. Because it affects the total life of the people, all government officers, particularly administrators, must be concerned with the extension programme for rural betterment; continuity is so essential to success that this important factor should be borne in mind by provincial administrations when staff postings are being considered in all departments to ensure good team work. To work with one section of the population alone, the adult male, is to ignore the potentialities of two-thirds of the population. Most agricultural extension services started to work only with farmers, but after a time it was found that the farm and home are so closely interconnected that it is impossible to go forward with one without the other, and extension programmes are prepared for home-making as well as for farming. Similarly the difficulty in persuading adults to change their customs led extension workers to develop programmes to attract youth. It is in youth that the habits of the next generation are formed.

The basis of all extension services is a country-wide staff of local practitioners—agents, representatives, advisory officers or agronomes, in charge of local units of administration, counties or districts — serving under regional directors, in charge of States or provinces, supported by staffs of subject-matter specialists. Extension plans are developed within the broad lines of national policy in co-operation with the people themselves, who are organized in clubs or committees at all levels, community, district, county, regional and national. The usual organization of Colonial Departments on the territorial basis of provinces, in charge of Assistant Directors, divided into tribal districts, in charge of Agricultural Officers, corresponding with the administrative organization of the

Colony, is excellent for extension purposes and corresponds with the set-up in most other countries. The provincial headquarters is ideally situated on a Provincial Experiment Station, where specialists — botanist (plant breeder), chemist (soils, manures and feeding stuffs), agricultural engineer (soil conservation), agricultural education officer (staff training and liaison with education department)—are located. The specialists serve the province in team with the district agricultural officers. District officers are located upon District Experiment Stations with a subordinate staff of assistants, instructors and demonstrators, distributed according to the tribal sub-divisions of the people.

It is seldom possible to provide staff for every district in the province. Reconnaissance survey indicates the order in which districts should be opened up as staff becomes available. It is generally better to concentrate limited staff in critical districts and to indicate the application of Government's general agricultural policy to the district administrative officers in the balance of the territory — supported by occasional inspection tours — than to dissipate energy over too large a field with the risk of achieving nothing everywhere. When a district has passed the initial extension stage, which generally takes from seven to ten years from the start of the survey, it may be possible for junior staff to carry on with occasional supervision and to divert senior staff to open up other districts. In this manner the province can eventually be covered by a limited senior staff with locally recruited extension personnel and a policy and programme developed and adapted for each set of conditions in every district. This way of working provides flexibility in the approach to local problems. The department may be in the initial experimental phase in one district and the extension phase in another, all working within the general lines of policy decided on colonial levels and interpreted by the assistant director working with his team of specialist and district officers. As districts are opened up, a detailed agricultural policy expands the original general policy for the region. The sum total of district policies make up provincial policy, leading to a sound colonial agricultural policy built up from provincial policies, the whole being solidly based with the tribal district or local government area as the unit.

The junior staff is the true extension staff of the department and too much attention cannot be paid to their selection and training. Upon their enthusiasm, confidence, patience and personality the whole success of the department depends. A rural background and a detailed knowledge of the system of farming it is desired to improve are of greater importance than academic qualifications; insistence upon the latter too often leads to recruitment of townsmen who can seldom make up later for lost early experience. Too often junior officers fail because they themselves have not confidence in the extension policy and they try to persuade farmers to take advice which they would not be prepared to follow on their own farms. Junior officers who have taken part in a survey develop a humble approach to the farmer and derive confidence and enthusiasm from a programme which they themselves recognize fits the local conditions; it is their job to close the gap. They take their tune from the District Agricultural Officer who should remain long enough in a district to be effective.

Extension must start on a level with the people and carry them forward, as a teacher does a class, a step at a time. The basis for an agricultural policy must be facts rather than opinions . For these reasons surveys must precede extension planning to indicate the problems for investigation, to provide a control for experiments, and to show how the answers to the problems can at a later stage be geared-in to local practice. This is the method of approach to planning followed in all advanced countries, and it is of even greater importance in the Colonies where in many cases the staff of a Department of Agriculture are alien and cannot live with local farmers nor speak with them fluently in their own language. Confusion has arisen when agricultural betterment has been approached without preliminary surveys. Too often programmes have been based upon guesswork, the needs of external markets, or the personal interests of the investigator rather than the facts regarding the needs of the local people. In districts where extension work is not making progress it would be well to check to see if the programme really does fit local conditions and if the staff are approaching the work in the approved manner. In such cases it will generally be found that the survey or local experience over a sufficient period is lacking or the extension programme is not based upon local trials.

Every society is unique in that it is the product of its own environment; that environment must be understood if the extension programme is to fit the circumstances. Broad classifications are possible as between literates and non-literates, between Anglo-American and peasants societies, between nomads and settled agriculturists, between cash and subsistence farmers, and so on. Basic human requirements are very similar, but generalizations cannot be carried too far even within any one group. Preliminary agricultural surveys must therefore be comprehensive and indicate local customs and social structure, and when results are being extended to other areas, no matter how similar superficially, cultural variations must be looked for which might influence the course of extension work. The assistance of a social anthropologist

would be valuable in preliminary surveys, but much can be achieved by agricultural officers aware of requirements. The possible repercussions of an extension policy upon the culture of a people are important. This is particularly true in the Colonies, where tribal life is highly integrated and a change in one activity affects a number of others. To neglect the sociological implications of an extension programme might lead at best to a waste of time through noncooperation, or else to the creation of new problems more serious perhaps than the first. For example, the effect of the introduction of a cash crop to a subsistence economy or of a permanent cash crop or mixed farming systems on native land tenure must be anticipated. Extension programmes must be flexible and continually subjected to review: they must march with the times. With the spread of a money economy, improved communications and the advance of education, all hastened by the effects of the war, cultural changes in the Colonies are proceeding very rapidly. Indigenous systems are fast breaking down under new economic stresses and strains, which invariably throw an extra strain upon the soil; it is in helping rural people to make the necessary adjustments that Departments of Agriculture have perhaps their biggest responsibility. By working-in closely with Native Authorities in extension work, it is possible to ensure that programmes fit the culture of the people and that changes produced by the programme do not become disruptive of native life.

When suitable answers have been found to immediate local problems, and only then, the extension phase can be entered upon and every appropriate extension method should be brought into play. Local leaders, who should be chiefs and family heads or outstanding individuals approved by them, are contacted in the first instance and every effort should be made to encourage the formation of farming group around them. The demonstration farm is generally an important extension method as the first step from the experiment station. The demonstration farm should be a farm of local unit size and pattern, incorporating the ideas it is desired to extend, the whole being capable of adoption by better local farmers. Demonstration plots on the farms of local co-operators may be employed effectively for demonstrating single factors. Demonstration would be accompanied by personal contacts with local leaders, general meetings, visual aids, short courses, loan schemes, seed supplies, agricultural shows and competitions, and so forth. If it is decided to link demonstration farm with schools, an agriculturist should be present on school site boards to ensure suitable farming land is adjacent. So often schools have been established on land which was vacant because nobody wanted it for farming and a valuable opportunity has been missed to give a genuine rural bias to the curriculum. In connection with school farms it should be remembered that their main function is education; not exercise nor, directly, reduction of the school messing account, desirable as this may be. The farm should demonstrate the principles of the local Department of Agriculture on a unit scale and should have an adequate paid labour force to make it independent of pupil labour. Pupils of course receive instruction on the farm, but the biggest value would come from a directed comparison between the school farm and neighbouring farms. The school farm should not be confused with the school garden. There is a place for a demonstration school garden to demonstrate intensive production and to supply protective foods in the diet, and it is desirable that provision be made for pupils to work in syndicates on garden plots where the growth of plants can be followed through from seed to harvest. The Department of Agriculture should retain full responsibility for policy and finance: management is a co-operative effort between the local agricultural instructor and the school authorities.

Agricultural extension workers maintain close contact with educationists in rural areas. In Canada and the United States the school section is often the community unit and the school house the meeting place for the community club. Many agricultural improvements which adults find it difficult to accept will become accepted practice by their children. If the world is to be adequately nourished and the drift to the towns is to be regulated, general education must have a bigger influence upon agriculture. In the Colonies the aim in rural schools should be to teach in an agricultural atmosphere, taking rural examples to illustrate class work, rather than to teach agriculture. Rural science and all that it might imply should replace nature study in the curriculum. One of the main difficulties in producing the right kind of rural atmosphere in schools in the Colonies is the urban background and the urban training and mentality of most of the teachers at the present time; agriculture is thought to be degrading, a sad indictment of an education policy transported direct from a pre-war industrial Britain. Many pupils have a sounder working knowledge of biology than their teachers. Useful changes are now being made in most Colonies in teachers' training courses by co-operation between Education and Agricultural Departments; but it will need time to take effect.

The farm and the home are inseparable; if agricultural extension work is to be fully effective in bringing about rural betterment, steps must be taken to enlighten rural women in up-to-date home-making methods. In Britain, the Women's Institute movement has grown from small beginnings in 1913 to an active body,

nationally federated with a membership of 379,000; instructresses are provided by local education authorities. In Canada, the home of the Women's Institute, the movement has steadily grown during the last fifty years. Le Cercle de Fermières operates in the French parts of Quebec Province. Both organizations work in closely with the Agricultural Representative Services. In the United States we see the fullest development of a unified rural extension programme, with each County Agricultural Agent working in co-operation with a woman Home Demonstration Agent — a graduate in domestic science from the State University — under the direction of the State Director for Extension. Subject-matter specialists in nutrition, child welfare, home crafts and junior club work are attached to State headquarters. Extension work is carried out through women's clubs organized on a village or community basis.

In the Colonies women play a vital role in rural life, being responsible for much of the field work, for marketing, drawing water, collecting firewood, building, making pottery and brewing beer, in addition to the usual domestic duties. It is true that native life is so closely integrated that indirectly all the work of a Department of Agriculture benefits both women and men, but a very good case could be made for having women workers, trained in domestic science, attached to Agricultural Departments. In Uganda, male Rural Assistants trained in domestic and village betterment are being tried out, also women Agricultural Instructresses. Shortage of agricultural staff and of educated women trainees is likely to limit development along these lines for some time to come, but it is not too early to plan for the future.

Continuity of personnel, both senior and subordinate, is vital to successful extension. There is no worse failing of the Colonial Service than the opportunist method of staff posting. In the United States the average length of service of the 3,000 county agents is ten years in the same county; many have served more than twenty. Extension aims at producing action in individuals, families and communities; success can be achieved only with an intimate knowledge of the people which cannot be acquired over a short period. To transfer an extension worker is like transplanting a tree, the fine contacts through the root hairs are broken. It is very desirable that the officer responsible for the initial survey should at least see the district developed to the extension stage. When the time comes to hand over a district, the handing-over period should be long enough to ensure that policy and goodwill remain unchanged. Policy should be based upon the facts shown by survey and experiment. Annual programmes of work should be based upon the previous annual report, prefaced by a short description of the area and a statement of policy which can be modified as development proceeds, in the light of new information. The team of district officers and specialists should be maintained within the province as far as possible. By working in this way, continuity of policy and outlook can be assured on a regional basis. District and provincial programmes of work should be discussed in conference by the officer in charge of a province with his senior staff within the province before submission to the Director for his consideration. It would make for better understanding and less friction and jealousy within a department if all provincial programmes could be considered together by provincial officers sitting in conference with the Director.

Fundamental to successful extension is the confidence of the people, which can be won by a policy based upon their requirements coupled with continuity of personnel. Extension programmes and approach must accord with indigenous institutions and customs. This can be best assured by associating extension work closely with the local government authorities. The secret of success in extension is to take first things first; centre the programme on the next step in local rural development—it may be the development of water supplies, the use of manure, or a plough, a disease resistant crop, a dry season fodder, a famine reserve or improved diet. Having achieved success in meeting one recognized local need, subsequent progress is less difficult and local co-operation is assured. The extension worker knows he is achieving success when the people start to set the pace. In developing a policy it should be remembered that it is the small advance by the many which generally counts for more than a great advance by a few. The production resulting from the application by 100,000 farmers of an extra half a ton of farmyard manure each would be of greater significance than the adoption of the plough by a hundred or so hand farmers though possibly less spectacular in an annual report. A few hundred wells, which the people have been taught to dig for themselves, will generally be of greater value than a single large dam however efficiently made with bulldozers. It is generally possible to divide policy into two parts, one part calling for general action, such as the control of erosion, the control of grass burning, the making of manure, or rotational grazing on communal pastures; the other appealing for individual action such as the use of a plough, the digging of a well, the planting of a fruit tree or a firewood plot, or the making of a vegetable garden. It makes for a better balanced programme, more effective employment of extension time, greater interest and therefore more effective work, when a dual policy can be developed in this way.

Problems of development and welfare in the Colonies are largely rural; there has been a tendency however for Colonial Governments to overlook the significance of well-balanced Departments of Agriculture in this respect and to build up new departments for social welfare mainly urban in outlook and approach. Given adequate funds and staff and a broader interpretation of their functions, Agricultural Departments have unquestionably a vital part to play in colonial betterment and their development represents a sound investment. Administrations should be made aware of this. In conclusion, Departments of Agriculture must never forget that it is the people who matter; not the soil, the crops, or the livestock except in their relation to the total prosperity and happiness of the people.

REVIEW

FIVE HUNDRED VARIETIES OF HERBAGE AND FODDER PLANTS

EDITED BY M. HALL. PUBLISHED *as Bulletin 39 of the Commonwealth Bureau of Pastures and Field Crops, Aberystwyth, Great Britain, 1948. pp. 316. 15s. net. Obtainable from the Central Sales Branch, Commonwealth Agricultural Bureau, Penglais, Aberystwyth, Great Britain.*

This bulletin brings together, in the form of a catalogue, data concerning a large number of varieties of herbage and fodder plants. Information has been received from specialists in many parts of the world and the aim has been to give for each variety details regarding origin, characteristics, adaptation, resistance, use, whether certified, whether grades are recognised, authority for certification, whether seed is obtainable on open market, etc. In the first part of the catalogue information is given about five hundred varieties arranged alphabetically according to genus and species; in the second part of the catalogue is indicated the Volume and place in "Herbage Abstracts" at which information on a particular variety can be found.

The editor states in the introduction: "It is fully expected that this attempt to bring under one cover for the first time all relevant data concerning a great number of varieties of plants used in one way or another as animal fodder will be open to criticism because of lack of uniformity in treatment, variations in standards of naming and certification of varieties, and the frequent use of synonyms. The object is to provide as much information as could be collected for this first edition and at the same time to draw attention to the general problem and to the need for action in various degrees and directions as far as recognition and naming of varieties, reduction in the number of synonyms, and other aspects are concerned. For many of the varieties listed the data are complete and the varietal names and characteristics are fully recognised and accepted; for many others the data are scanty and can be regarded as only provisional in this edition. Countries differ widely in the degree of authenticity which they require for their recognized varieties."

The majority of the data relates, of course, to the fodder species of temperate regions; data are given about numerous varieties of each of the important temperate fodders, as oats, mangolds, cocksfoot, timothy, perennial rye grass, lucerne, white clover etc; inevitably, due to lack of space, many species have had to be omitted altogether. The worker in the tropics will find comparatively few tropical fodder species included; of the fodders used in the tropics, species such as Rhodes grass, soya beans, maize and sorghums are included, though in most cases varieties are described from countries such as Palestine, N. India, S. Africa, which are outside the true tropics. This bulletin may, in fact, serve to remind the worker in the tropics of the paucity of descriptive data about the many varieties of tropical fodder species which are grown in the various parts of the tropics. For instance the many different varieties of elephant grass *Pennisetum purpureum* and of guinea grass *Panicum maximum* need to be identified and described and their nomenclature standardised; and there is disappointingly little published data about tropical forage legumes such as *Centrosema, Indigofera,* and *Pueraria* spp. Now that there is greater realisation, in most parts of the tropics, of the importance of developing useful forage grasses and legumes for inclusion in local agricultural systems it is to be hoped that workers will find time to publish information on local forage species and that we may look forward to the publication at some future date of a catalogue of five hundred varieties of tropical herbage and fodder plants, which will be as valuable to the worker in the tropics as the present bulletin will certainly be to the worker in temperate countries.

L. J. C. E.

OBITUARY

Sir Frank Stockdale, G.C.M.G., C.B.E., M.A., F.L.S.

With the sudden death of Sir Frank Stockdale on 3rd August 1949, the Colonial Empire lost one of its most distinguished servants and the Colonial Agricultural Service the man who probably more than any other was the architect of its present structure.

Frank Arthur Stockdale was born on 24th June, 1883. Educated at Wisbech and at Magdalene College, Cambridge, he entered the Colonial Service as Mycologist in the Imperial Department of Agriculture for the West Indies in 1905. Three years later he became Assistant Director of Science and Agriculture and Government Botanist in British Guiana and at the early age of 29 he was appointed Director of Agriculture in Mauritius. Four years after this he became Director of Agriculture in Ceylon, where he remained for 13 years.

With his wide knowledge and experience, great administrative gifts and outstanding personality, he was marked out for work of wider scope and influence, and his opportunity came with his appointment in 1929 as the first Agricultural Adviser to the Secretary of State for the Colonies. In the next twenty years he visited all parts of the Colonial Empire (except the Falkland Islands), most of them many times, and acquired an unrivalled and exhaustive knowledge of their agriculture, their problems, and their men.

In 1940 he was appointed to the newly-created post, recommended in the Moyne Commission's report on the West Indies, of Comptroller for Development and Welfare in the West Indies. With its headquarters in Barbados, the "Stockdale circus", with an annual grant of £1 million, extended its influence throughout the British Caribbean and was responsible for launching many schemes to develop the economies and promote the prosperity of the various colonies, with their widely differing conditions and needs. From 1942 to 1945 he was also British co-chairman of the Anglo-American Caribbean Commission.

In 1945, when the organisation in the West Indies was well established and running smoothly, Stockdale was brought back to London for the new post of Adviser on Development Planning in the Colonial Office. With the host of post-war problems to be tackled, nobody could have been better suited to this key post. He was indeed a mine of information and an unfailing source of shrewd constructive advice. Whenever any difficult problem arose respecting conditions or development in any Colony, the instinctive reaction was "Let's ask Stockdale", —and seldom could he not help.

In 1948, on his retirement from Government service, he became Deputy-Chairman of the new Colonial Development Corporation, a fitting culmination of his career, and he was in active work in that job when he died peacefully and unexpectedly in his sleep.

When Stockdale went to Whitehall in 1929 the Colonial Agricultural Service scarcely existed even in name; the problems and needs of each dependency, and the work and organisation of each Department of Agriculture, were treated largely independently on their own merits. When he left for the West Indies in 1940 it was well on the way to becoming an integrated whole, and the greatest share in bringing this about was Stockdale's. On his return to Whitehall in 1945, though he was no longer directly responsible for the Service, his influence from the key position he then held in the Colonial Office was still a powerful one. The Colonial Agricultural Service is still developing towards the unified whole which he envisaged and on the firm foundations which he laid.

Although he could take no direct part in the establishment of the Imperial College of Tropical Agriculture in Trinidad in the early '20s, he became a member of its Governing Body on his appointment to the Colonial Office in 1929, and from then onwards he took an important part in its affairs. His retirement from Government service in 1948 made it possible for him to step into the breach caused by the retirement of Sir Eric Macfadyen and to become Chairman of the Governing Body—alas, for only one short year. He took a close personal interest in the College and fully recognised its key position as a post-graduate training centre for agricultural officers and specialists to serve throughout the Colonial Empire. Although I had known him and had valued his friendship and counsel for many years it was only on my coming to the College in 1947 that I was brought into close and constant contact with him.

There was about Stockdale a serenity and quiet manner, a calmness of purpose, which concealed an enormous fund of energy. He got things done without any fuss but with efficiency, speed and judgment. His encyclopaedic knowledge of men and affairs, of matters scientific and administrative, was always freely at the disposal of others. His shrewd judgment and calm wisdom were coupled with a geniality and an impish sense of humour — he commonly had a twinkle in his eye, and he gained the affection of all who had much to do with him.

The fruits of his wide knowledge and ripe experience were never more needed than now and his death is a tragic loss to the Commonwealth no less than to the College. One had got so used to having his counsel available that it came to be unconsciously taken for granted, and it is only now that he is gone that the full breadth and depth of the man are realised.

All his great achievements were not accomplished without an enormous capacity for constant hard work. The death of his wife and lifelong companion less than a year ago was a great blow to him, and he seemed to immerse himself even more deeply in his work. Although he appeared to be in as hearty health as ever, he evidently overtaxed his strength; he died as he would have wished, in the fulness of his powers and firmly in the saddle. I was with him in his office on the last afternoon of his life: he was in his usual good spirits and his last words to me as we parted at 6 o'clock were: "Don't wait for me, I must collect my 'home-work' before I go". He passed on in his sleep that night.

H. J. P.

Sir Norman Lamont (bart.)

The College has lost one of its oldest and firmest friends by the death of Sir Norman Lamont. As long ago as 1902 he affirmed that "the crying need of the West Indian Colonies is a University of Tropical Agriculture" and considered that "the recently constituted Imperial Department of Agriculture.....would form an excellent nucleus for such a University." Twenty years later this dream materialised with Sir Norman as one of the original Governors, and from then until his death he never ceased to take a keen and active interest in all College affairs. He resigned from the Governing Body in 1945 because difficulties of travel made it impossible for him to attend meetings regularly, but he repeatedly expressed his regret at having come to this decision.

The College excursions to Palmiste invariably attracted a full attendance of staff and students. Thoughtful planning by Sir Norman and his lieutenant and friend Augustus endowed the visits with a high educational value, but the lunches rendered the occasions even more memorable. Sir Norman took pride in the fact that everything served at table was produced on the Estate. A typical menu of oysters, crab backs, pastelles, mutton and sucking pig, mountain cabbage, coconut ice-cream, fruits and coffee shows that Sir Norman practised, as well as preached, a wide diversification of agriculture. Visitors from North of the border were accorded a special treat — the Cross of St. Andrew flying proudly from the flagstaff at the Great House.

Sir Norman played an active and distinguished part in public affairs, both in the United Kingdom and in Trinidad and Tobago. He was M.P. for Bute from 1905 to 1910 and served as Private Secretary, first to Sir Henry Campbell Bannerman and later to Mr. Winston Churchill. He was chairman of the West India Association of Glasgow from 1940 to 1947, and a Member of the Executive of the West India Committee for a like period. He served as a member of the Legislative Council of Trinidad and Tobago from 1915 to 1923, where his contributions to debates were characterised by polished phrases and constructive criticism. He was a Member of the Board of Agriculture and had a special affection for the Naparima Agricultural Society which he served as President for many years. Sir Norman was in great demand as a public speaker. His address to the Historical Society of Trinidad and Tobago in 1936 on *The Life of a West Indian Planter 100 Years Ago* was delivered to an audience that packed the hall and overflowed into the galleries and staircase of the Government Training College. Many of his major speeches and writings were collected and published in *Problems of the Antilles* (1912); *Inventory of Lamont Papers* (1914); *Problems of Trinidad* (1923); and *Gleanings* (1927).

Sir Norman was a keen collector of butterflies and moths, and it is largely due to his activities over a long period of years that these are better known than any other large group of insects in Trinidad, no less than 1,800 species being recorded. W. J. Kaye in his catalogue of the Trinidad Butterflies acknowledges the invaluable help he received from Sir Norman, and under their joint authorship a catalogue of the Trinidad moths was published in 1927. Sir Norman recently compiled a list of additions to this catalogue which it is hoped to publish in 1950.

No one who enjoyed Sir Norman's hospitality, either at Palmiste in Trinidad or at Knockdow in Scotland, could fail to be impressed by those many unobtrusive attentions that made him the perfect host. His demeanour in public and private life was always that of a laird and a gentleman. Sir Norman left no heir, but a host of friends will cherish his memory.

C.Y.S.

"Let us now praise famous men:
Men renowned for their power,
Giving counsel by their understanding:
Leaders of the people by their counsels,
And by their knowledge of learning meet for the people,
Wise and eloquent in their instructions:
Rich men furnished with ability,
Living peaceably in their habitations."

BANANA RESEARCH AT I.C.T.A.

BY

E. E. Cheesman

(Formerly Professor of Botany at the Imperial College of Tropical Agriculture).

Introduction

This is a review of botanical researches on bananas carried out at the Imperial College of Tropical Agriculture from 1922 to 1946, and of the present programme. Various findings have been published from time to time in scientific papers, where they are available to the few botanists who are interested in the intricacies of reproduction and heredity in *Musa*. The object here is not to report any new discoveries, but to give an account of the work as a whole that may be of some interest to a wider circle ; and the approach is therefore as untechnical as it can be made, having regard to the highly technical nature of the subject. If apology is needed for repetition of some facts about the earlier work that have already been published more than once, it must be pleaded that the last comprehensive review appeared in 1934, and many readers are likely to find it more convenient to have the historical background redrawn than to be obliged to refer back to earlier publications.

As the paper is essentially a progress report of the Department of Botany, and not a review of banana breeding in general, there is little reference herein to the extensive work that has been carried out concurrently by the Jamaica Department of Agriculture. The omission in no sense implies neglect. On the contrary, the two programmes in Jamaica and Trinidad have been carried on co-operatively, have influenced each other in many ways, and have produced broadly complementary results. To a lesser extent, but still materially, the genetical programme has been influenced by other lines of banana research, especially the investigations into Banana Wilt and into fruit storage and transport pursued by other departments of the College, but those also fall outside the scope of this summary.

The Development of The Programme

The first systematic attempts ever made at breeding new varieties of bananas were begun by the College at its inception in 1922. Their immediate aim was to produce a new export banana resistant to Banana Wilt (Panama Disease), which was causing grave concern by its ravages on the established Gros Michel variety in Jamaica and elsewhere. The inspiration of the work was largely drawn from the success that had attended the raising of new sugar canes from seed in the thirty years preceding. The amount of useful information available was very slender, and it can now be said without the slightest disrespect that nobody concerned had any conception of the magnitude of the task undertaken. Not only was specific information lacking about the genetics of bananas, but knowledge of a more general kind about genetic systems in plants, and particularly about the cytogenetics of sterility, was rudimentary by comparison with what it is today.

In these circumstances the programme opened with investigation of the possibilities of producing seeds in the few edible banana varieties available, whilst efforts were made to get together a collection of varieties for more extensive survey. Evidence was soon found that no good results were likely to be had from crosses between edible banana varieties alone ; but there happened to be two species of *Musa* in the botanical gardens in Port-of-Spain with inedible fully seeded fruits, and from pollinations by one of these (later identified as a form of *M. acuminata* Colla) seeds were obtained in Gros Michel fruit at a rate of about one per bunch. A few of these seeds germinated, and the first artificially produced hybrid banana flowered in March 1925.

This first hybrid (I.C. 1) showed a closer resemblance to a commercial banana than might have been expected, considering the characters of its male parent. It was, in fact, an edible banana as good in all its characters as several that are in cultivation, but showed certain defects that unfitted it for the export trade. Compared with the standard Gros Michel it had a rather less symmetrical bunch, a slightly lower number of " hands " and a shorter fruit, and it also showed a tendency to produce occasional seeds. All these shortcomings were quantitatively small, and when I.C. 1 proved to be highly resistant to Panama disease, it gave rise to hopes that the whole problem might be fairly easily solved. The next step was to repeat the cross on a large scale in the hope that among a large enough number of seedlings the desired type might occur. At the same time I.C. 1 after bulking up could (as it produced fairly abundant pollen) be self-fertilized, back-crossed with its parents, and used as a male parent on other edible varieties.

Such then was the programme in its second phase, but hopes were not realized. Repetition of the cross gave a series of F1 hybrids which varied little from the first example. Some were susceptible to Wilt, and some were in other ways inferior to I.C. 1. One plant (I.C. 2) seemed a little nearer the desired type, especially in being less liable to produce seeds on selfing, and this was released for commercial trials in 1932.

By that time it had become apparent that attainment of the ideal was going to be a long task, and that an interim solution of the problem might be better than none, but I.C. 2 was not regarded as more than that.

Attempts to carry the breeding into later generations gave even less favourable results. Seeds were not readily obtained by selfing or intercrossing F1 plants, and the few F2 seedlings raised all proved inferior to their parents. Backcrossing the F1 to Gros Michel, which was expected to give the best results, was a failure; and backcrossing to the male parent gave, as was expected, plants much inferior to the F1.

These results were partially explained by cytological studies, which were added to the programme as soon as I.C. 1 flowered. It had been realized from the start that in a crop as sterile as the banana there must be irregularity in the reproductive mechanism, and that cytological information would be useful. Examination revealed differences in chromosome number between the parents and the hybrids showing that polyploidy was involved.

The original cross had been between a triploid (Gros Michel) and a diploid (*M. acuminata*) and had produced a tetraploid (I.C. 1). Much later, after examination of a wide range of material, it was found possible to generalize the situation as follows:

1. The basic chromosome number in the section of *Musa* to which the edible bananas belong is $x = 11$.

2. The fertile species (*M. acuminata*) used in the initial experiments and all others of the same section that have been acquired since are diploids ($2n = 22$).

3. Most edible bananas are, like Gros Michel, triploid; though a few are diploid.

4. All the best of the F1 hybrids obtained from triploid x diploid crosses are, like I.C. 1, tetraploid ($2n = 44$). Diploids, triploids and aneuploids are also obtained, but none of these approaches as closely as the tetraploids to the characters of a commercial banana.

5. Crossing tetraploids together produces more tetraploids, but these are always inferior to their parents.

6. Crossing triploids with tetraploids (as in the cross Gros Michel x I.C. 1) gives pentaploids and higher polyploids, all of which are commercially worthless.

These generalizations were only arrived at after a great deal of empirical work in what may be regarded as the third phase of the researches. The variety collection was growing steadily, and as the available material increased, a comprehensive programme of cross-pollinations developed. Between 1927 and 1941 the number of inflorescences pollinated was nearly 6,000 and hundreds of seedlings were grown and observed. The policy in this phase was to leave no possible line of attack untried, and even when negative results were obtained, to repeat the cross until the accumulation of failures demonstrated conclusively that it was useless.

In this way the problem was slowly defined and narrowed down by a series of eliminations. The edible varieties were classified into those that give no progeny at all (a class containing some members that would otherwise appear to be very useful material), those that give predominantly diploid or aneuploid progeny of no apparent value for further breeding, and those that give predominantly tetraploid progeny. From the last class a series of tetraploids was raised by crossing with various fertile diploids, and the teraploids were then crossed together or back-crossed to triploids.

From all this work nothing of direct economic value was obtained, but the effort was not wasted. The workers engaged in it learned thoroughly, as it could be learned in no other way, the behaviour of the diverse material in all types of crosses — diploid with diploid, diploid with triploid, diploid with tetraploid, triploid with tetraploid and tetraploid with tetraploid. They were able to establish beyond doubt that intermediate expression of characters is the rule in *Musa* crosses. The interfertility of the species of *Musa* was found to be surprisingly wide, and even edible bananas sometimes give progeny with species not very closely related to them. But it is rare for characters not present in either parent to appear in the offspring, and when extra-parental characters do appear they are usually unimportant ones or deficiencies. Consequently it was found possible to predict within fairly narrow limits what the offspring of any given cross would look like, with respect to such important characters as angle of bunch, number and size of fruits, and so on. Previously there had always been at least the theoretical chance that a good banana might result from a cross between "unlikely" parents, but accumulated experience showed the chance was so small as to be negligible. Henceforth parents could be chosen on the sum of their phenotypic characters, just as in most simpler plant breeding programmes, subject only to allowance being made for polyploidy, which often causes the characters of one plant to be more pronounced in the offspring than those of the other parent.

The establishment of this fact and of the cytogenetical generalizations already mentioned may be regarded as marking the end of the empirical phase of the researches, though there was no abrupt change of plan at any point but rather a gradual modification as information ac-

cumulated. With increasing knowledge of genetic behaviour came an increasing conviction that failure to reach the desired goal was largely, if not entirely, due to lack of the right breeding material. Emphasis had always been laid on the necessity for a large variety collection from which suitable material could be chosen; it came to rest more and more on the necessity for that collection to contain a wider range of fertile diploid forms, only obtainable by collection in the countries where they are indigenous.

The genetical and cytological data obtained indicate that the good qualities of tetraploid hybrids of the I.C. 1 type depend on the fact that they contain the complete gene-complex of their triploid female parents, whilst their defects derive from the added (haploid) gene-complex of their diploid male parents. The constitution of the parental triploids has been evolved through the accumulation of structural changes during hundreds of years of vegetative propagation, and can only reach its full expression as long as it works as an undisturbed unit. The defects of the tetraploids therefore cannot be removed in later generations, because in sexual reproduction of the tetraploid the unit is inevitably broken up, and the chances of recombining it are too remote to afford a basis for practical breeding. This theoretical appraisal of the situation by K. S. Dodds is supported by the actual results of tetraploid x tetraploid crosses, and forms the foundation of further attempts to produce a commercial tetraploid.

For the triploid or female side of the cross that is to give a useful export banana, everything points to the Gros Michel variety as the best available parent. Apart from its susceptibility to certain diseases, that variety has so many of the qualities required in the export trade that somebody has said it might have been specially created for the fruit industry. Many years' study of other established varieties by the fruit trade, as well as our own observations in Trinidad, have failed to find a satisfactory substitute for it, and to start with any other parent is to add unnecessary handicaps in a problem sufficiently difficult without them. At one time attention was given to the possibility of starting with an established variety immune to Wilt and trying to improve its commercial fruit characters, but there are several reasons why this is no longer considered feasible. The chief is that the most promising varieties for such a programme are completely sterile, which is one of the pieces of useful information accruing from negative results in the empirical investigations. Apart from that is the fundamental consideration that introduction of disease resistance by itself has proved the simplest part of the whole problem, whilst it is the commercial fruit characters that give all the trouble. Disease resistance is the rule rather than the exception amongst the fertile diploids. Thus in practice any male parent which would improve the fruit characters of an inferior variety would almost certainly give even better results on Gros Michel and solve the whole problem outright.

Virtually then, the problem narrows down to getting the right male-fertile diploid for crossing with Gros Michel. Such a plant may exist in a wild state in countries where *Musa* is indigenous, or it may have to be built up from a number of forms each good in some characters but deficient in others. If it could be found ready-made much time would be saved, as the synthesis from such material as is now available would at the best be a tedious undertaking. Strong representations to that effect having been made, plans were approved in 1939 for an expedition to the Far East to explore the variation of the nearest banana relatives in the wild state and to collect material of promising forms.

For reasons explained more fully in a later section of this paper, the region chosen for the first exploration was approximately that where Burma, Siam and Indo-China meet. It would be impossible to explore the whole of the vast area over which *Musa* is indigenous, and even the section of the genus that appears to be of the greatest interest covers an enormous area, but the centre of distribution seems from available evidence to be in the region specified.

Plans were suspended on the outbreak of war, and the political condition of the countries named does not at the time of writing afford much hope of their early resuscitation. The policy since 1940 has therefore been to concentrate on genetical researches, collecting data likely to hasten progress when new material becomes available, and at the same time to try how far a suitable diploid can be built up from the existing stocks.

Present Aims

The immediate or "short-range" aim of banana research is still to produce a new export variety resistant to Banana Wilt, otherwise known as Panama Disease, caused by the soil-inhabiting fungus *Fusarium oxysporum cubense*. But without neglecting this object it is now possible to state aims in rather broader terms. Since the work started, additional urgency has been lent to it by the rapid spread in the Western Tropics of the Leaf-spot Disease caused by *Cercospora musae* Zimm. Though the latter disease, unlike Wilt, has proved to be controllable by other means, a resistant variety would afford cheaper control than the present method of spraying. In the background there is always present the threat to the export trade of Bunchy Top, a virus disease that already causes serious losses in the East; and beyond that there is the possibility that at any time a

new or hitherto unimportant disease may become prominent and create a need for further breeding. The problems of the banana as a local food crop have hitherto scarcely existed, partly because diseases are less serious when the plants are grown as scattered individuals among other species and partly because so many varieties are available that suitable ones can usually be found for any set of local conditions within banana-growing districts. This happy state of affairs may not always exist, and already the difficulty experienced in growing plantains in some districts points to wider uses for banana breeding.

There are good reasons, therefore, why banana research should be regarded as having a "long-range" aim quite consistent with its more immediate object. In other words, without for a moment losing sight of the urgent need for a "wilt-resistant Gros Michel" we may remind ourselves that the production of that plant is not likely to end banana-breeding. The long-range aim must be to obtain such a complete knowledge of genetic systems in *Musa* that new bananas can be bred as they may be required to meet any new problems that may arise in banana production.

Analysis of Problem

Disease resistance, though it is the primary desideratum, may fairly be said to present only a secondary problem. Resistance, both to Wilt and to Leaf-spot, occurs in many members of the banana complex, wild and cultivated, and is known to be transmissible. The primary problem is how to breed *any* commercial banana, in face of the fact that the essential character of a banana (its "edibility") is inseparably coupled with sterility.

The existing commercial bananas are undoubtedly the products of centuries of evolution. We do not know how long Man has been cultivating them, and selecting and preserving chance variations giving fruit more to his liking than that of wild plants, but it must be a long time. It happens that all the best of the varieties so produced are triploid plants, and there is probably a reason for that fact which still has to be found, and which is likely to prove important.

So far, the only practicable method that has been found for utilizing these products of long evolution in breeding is to *add* to them a gene-complex that will not detract from their good qualities and so to produce from them primary tetraploids. That is at present the main hope of solution of the short-range problem, and it looks a very fair one if the right material can be found.

The breeding of primary tetraploids, however, is no answer to the long-range question, which is, in essence, whether it is possible to imitate in a few controlled generations the process of centuries that has built up the primary triploids. Only when that can be done shall we be in a relatively safe position to meet the problems of the future in banana production.

The information required to that end covers a wide field of research, which may be appreciated by dividing it for discussion into five parts, although each line of work is dependent on the others. We need :

1. Studies of a wide range of cultivated bananas, which must include attempts to discover their constitution by genetical methods.

2. Studies of wild species of *Musa,* primarily to determine which of them have been involved in the ancestry of the cultivated forms.

3. Studies of the incidence of polyploidy and the general breeding behaviour of diploids, triploids and tetraploids.

4. Studies of the incidence and inheritance of parthenocarpy, with attempts to discover the physiological mechanism through which it is expressed.

5. Analysis of the several causes of sterility in various forms of *Musa.*

Each of these lines has in fact already received attention, since the observations incidental to the empirical attempts at banana breeding have provided a mass of relevant data and also material for further research. Each of them, however, still provides unsolved problems and must still be followed up. The position reached along each line will be briefly indicated.

Survey of Cultivated Forms

Nobody knows how many established varieties of bananas and plantains there are in cultivation. Most of the literature about the group emphasizes its diversity, but varietal studies tend to suggest that the diversity has been somewhat exaggerated. The question is not unimportant to the geneticist, for it affects fundamentally the picture that he must try to draw of the origins of the group.

In seeking the answer, we have first to define the term "variety". If we interpret it in its narrowest sense and apply it to every recognizable form, the total number may well be several hundreds. Some of these "varieties", however, will then differ from others only in single characters, such as colour of fruit or amount of wax on the epidermis. In such cases it is a justifiable assumption that two or more forms are descended from the same original seedling and that the variation has arisen through somatic mutation. There is plenty of evidence that somatic mutation (or "bud sporting") has played a part in the evolution

of banana varieties: for example, in Jamaica Larter (Journ. Jamaica Agr. Soc. August 1934) has described no less than six bud mutants of the Gros Michel variety found in commercial plantations.

The important question to the geneticist is how many original zygotes are represented, or in other words from how many distinct individual seedlings the present population has been derived by vegetative propagation. It is not likely that an exact answer will ever be obtained, nor is a very close estimate necessary, but it should at least be possible to determine whether the number is to be measured in dozens or hundreds. At present, all we can say is that edible bananas have certainly been derived in more than one way from a number of different wild forms. The usefulness of knowing approximately the kinds of wild plants that were originally involved, and the steps by which their constitutions have been modified, should need no stress.

There are therefore ample reasons for the maintenance and continued study of a wide collection of edible bananas, in spite of the decision that for immediate breeding purposes the Gros Michel is the only one likely to prove useful. Every new variety that comes into the collection adds something to the sum of knowledge about the group; and a variety quite useless as breeding material may, by closing a gap in the research worker's information, contribute greatly to final success.

Studies to date on the existing collection have led to the hypothesis that all Indo-Malayan bananas and plantains can be classified into three main groups, derived from two natural species and hybrids between the two. This hypothesis provides a great simplification of the origins of the group, but the danger is that it may prove to be an over-simplification, based on an insufficient range of evidence. Observations in the future must therefore be directed to checking the hypothesis and if necessary amending it.

Survey of Wild Forms

The wild forms of *Musa* are of most immediate interest because it is among them that we hope to find the right male parent to solve the problem of the "wilt-resistant Gros Michel". They have still more importance in the long-range problem of determining the origins and relationships of bananas in general.

The literature in 1922 contained well over a hundred specific names published under *Musa*, with good or fair descriptions of about forty species, classified into three subgenera and distributed over practically the whole of the Old World tropics. The relationship of the cultivated forms to the wild was little understood and theories about it conflicted. The first problem was therefore to find out how many species were probably concerned in the ancestry of the bananas or sufficiently closely related to be potential breeding material, in order that effort could be concentrated on the collection and study of those instead of being dissipated over an unnecessarily wide field.

This kind of problem has to be tackled by the collation of information from several sources. Much can be obtained from literature, though it is widely scattered and often in publications difficult to obtain. Some can be got from dried fragments in herbaria. More is forthcoming from correspondence and most from the material that comes into the collection by the good offices of co-operative correspondents in many countries.

By such methods it has been possible to arrange the available knowledge of *Musa* and step by step to eliminate large sections of the genus as not sufficiently closely related to the bananas to be potential breeding material. Recent publications have suggested the removal of a number of species to the genus *Ensete* Horan., and the classification of those remaining into four sections. Of the four sections only one (*Eumusa*) is judged to be involved in the banana complex, and it consists of no more than half a dozen described species. Of these, as noted above, only two seem to be directly involved in the ancestry of the bananas, but these two are widely distributed and variable, one of them extremely variable.

Our knowledge of these particularly important species is still fragmentary, but enough to show that they are by no means simple. Even in wild forms there are certain irregularities in the reproductive mechanism which must certainly be understood before we can hope to analyse the much more complex systems of the cultivated plants. Again it is only by survey of a sufficiently wide range of material that gaps in knowledge can be filled in.

Polyploidy

Gros Michel and the majority of edible bananas are triploid ($2n = 33$). All known wild species are diploid ($2n = 22$). The economic significance of the triploid condition is still obscure. The occurrence of perfectly edible (parthenocarpic and seedless) diploids among the established varieties shows that polyploidy is not an essential character of an edible banana. On the other hand, all the edible diploids known to us are slenderer plants than the average triploid and produce smaller fruits. There may well be some connection between polyploidy and fruit size, but it would not appear to be a simple or direct one. Tetraploids and higher polyploids

are only known among artificially produced hybrids and nothing higher than a pentaploid has ever been raised to flowering: even pentaploids are not very vigorous. Interest therefore centres mainly on the triploids and tetraploids.

As triploidy introduces further complications into a genetic system which is already complicated in the parthenocarpic diploids, little has been done towards the direct cytogenetical analysis of the triploid clones. The principle has been to work from the simpler to the more complex, and this means that most work to date has been done on the diploids.

Polyploidy has, however, been studied further in species hybrids where it is not associated with parthenocarpy; and one of the most interesting results is the finding that in *Musa* polyploidy frequently occurs as a result of wide species crossing. Several species hybrids, when selfed or backcrossed with their parents give either triploid or pentaploid progeny, or a mixture of both.

How far this information may ultimately help to explain the origin of polyploidy in the edible bananas cannot be stated. But it is evidently a useful addition to our knowledge of genetical behaviour in the genus.

Parthenocarpy

Parthenocarpy is essential in an "edible" banana, and therefore of the greatest importance. One difficulty in studying it is that it seems to be inseparable from some degree of female sterility. A parthenocarpic form may, however, be fully fertile on the male side, and studies of inheritance are therefore possible. Detailed results of such studies by Dodds and Simmonds are at present * in the Press. They show *inter alia* that parthenocarpy can be transmitted through the pollen of parthenocarpic forms, and that it depends on a single dominant gene, though its expression is affected by modifiers.

Parthenocarpy has so far been reported in *Musa* in only three species, two of which are the putative parents of the Indo-Malayan bananas. Even those species have numerous non-parthenocarpic forms, and parthenocarpy has not so far been induced in any form where it does not occur naturally. Knowledge of its behaviour has, however, already been turned to account in the synthesis of one banana variety. A cross between a parthenocarpic, male-fertile, diploid form of *M. acuminata* Colla and a non-parthenocarpic diploid form of *M. Balbisiana* Colla gave a plant closely similar to an established variety carried in the collection as Type 20. The result not only helps to prove the hybrid nature of Type 20, but may be regarded as probably only the first step towards further success in the synthesis of genotypes imitating established varieties with great consequent gains in our knowledge of the constitutions of those varieties.

Sterility

Sterility in the bananas is of practical importance whether regarded as an essential feature of any commercial genotype or as the greatest obstacle to breeding operations. From either point of view the analysis of its causes is necessary.

Research to date indicates that some female sterility is probably inseparable from parthenocarpy, representing another expression of the same factors. Some sterility of both sexes in triploids must be ascribable directly to the triploid state. In addition to these causes, structural sterility, which can be demonstrated in certain non-parthenocarpic diploids, must complicate the situation in the parthenocarpic polyploids. In certain clones, though not in all, there is good evidence of species hybridity as a possible fourth factor inducing sterility.

The investigation of sterility thus provides a connecting link between botanical survey, studies of polyploidy, and studies of parthenocarpy. Direct analysis of the complicated forms must be written off for some time to come as quite impossible. But by proceeding from the simpler forms to others a little more complex, and working simultaneously along the several lines that have been discussed, progress is being made.

Summary

An account has been given of botanical researches on bananas at the Imperial College of Tropical Agriculture since 1922.

The immediate object of the researches is the production of a commercial banana combining resistance to certain diseases with suitability for the export trade.

The long-range object pursued simultaneously is to obtain such knowledge of the origins, relationships, and genetic systems of the group as will facilitate banana breeding in general in case new needs for it arise.

Many years were spent in attempts to produce the desired type by methods that are largely empirical; but the information so obtained finally permitted analysis of the problem and formulation of a more scientific programme.

An attempt has been made to show how botanical studies of wild and cultivated forms, and studies of polyploidy, parthenocarpy and sterility have to be integrated to the desired end.

* *i.e.* in July 1948.

Publications

The following is a chronological list of papers on the botany and breeding of bananas (excluding pathology and fruit storage research) that have been published from the Imperial College of Tropical Agriculture :—

1925. Dash, J. S. — Bananas from seed. *Proc. 9th W.I. Agric. Conf., Jamaica,* 1924, pp. 53-56.

1928. Harland, S. C. — Bananas and Citrus. *Trop. Agriculture (Trin.) 5 :* 23-24, 54-56, 90-91.

1931. Cheesman, E. E. — Banana breeding at the Imperial College of Tropical Agriculture. *Empire Marketing Board Publ.* 47, H.M.S.O., London.

Cheesman, E. E., A note on *Musa ornata.* Kew Bull. 1931 ; 297-99.

1932. Cheesman, E. E. — Genetic and cytological studies of *Musa* L. I. Certain hybrids of the Gros Michel banana. *J. Genet. 26 :* 291-312.

Cheesman, E. E. — Genetic and cytological studies of *Musa* L. II. Hybrids of the Mysore banana. *J. Genet. 26 :* 313-16.

Cheesman, E. E. — Gros Michel and Pisang Embun. *Trop. Agriculture (Trin.) 9 :* 87 and 166.

1933. Cheesman, E. E. — Mutant types of the Dwarf banana. *Trop. Agriculture (Trin.) 10 :* 4-5.

Cheesman, E. E., Wardlaw, C. W. and Spencer, G. E. L. — The Cavendish group of banana varieties, with special reference to Lacatan. *Trop. Agriculture (Trin.) 10 :* 218-221.

1934. Cheesman, E. E. — Principles of banana breeding. *Trop. Agriculture (Trin.) 11 :* 132-37 ; 176-81 ; 203-208. (Reprinted with change of pagination as *Memoirs of the Imperial College of Tropical Agriculture, Botanical Secries* No. 3, 1934).

1935. Cheesman, E. E. and Larter, L. N. H. — Genetical and cytological studies of *Musa* L. III. Chromosome numbers in the Musaceae. *J. Genet. 30 :* 31-52.

1937. Cheesman, E. E. and Wardlaw, C. W. — Specific and varietal susceptibility of bananas to Cercospora leaf spot. *Trop. Agriculture (Trin.) 14 :* 335-36.

1942. Cheesman, E. E. and Dodds, K. S. — Genetical and cytological studies of *Musa* L. IV. Certain triploid clones. *J. Genet. 43 :* 337-57.

1943. Dodds, K. S. — Genetical and cytological studies of *Musa* L. V. Certain edible diploids. *J. Genet. 45 :* 113-138.

Dodds, K. S. — The genetic system of banana varieties in relation to banana breeding. *Empire J. Expt. Agric. 11 :* 89-98.

1945. Dodds, K. S. — Genetical and cytological studies of *Musa* L. VI. The development of the female cells of certain edible diploids. *J. Genet. 46 :* 161-179.

1946. Dodds, K. S. and Pittendrigh, C. S. — Genetical and cytological studies of *Musa* L. VII. Certain aspects of polyploidy. *J. Genet. 47 :* 162-177.

Dodds, K. S. and Simmonds, N. W. — Genetical and cytological studies of *Musa* L. VIII. The formation of polyploid spores. *J. Genet. 47 :* 223-241.

Dodds, K. S. — Musa Fehi. *Nature 157 :* 729-730.

1947. Cheesman, E. E. — The genus Ensete Horan. *Kew Bull.* 1947 : 97-106.

Cheesman, E. E. — A new classification of the genus *Musa* L. *Kew Bull.* 1947 : 106-117.

1948. Cheesman, E. E. — Notes on species of *Musa* L. *Kew Bull.* 1948.

Dodds, K. S. and Simmonds, N. W.—Genetical and cytological studies of *Musa* L. IX. The origin of an edible diploid and the significance of interspecific hybridisation in the banana complex. *J. Genet. 48 :* 285-296.

Dodds, K. S. and Simmonds, N. W. — Sterility and parthenocarpy in diploid hybrids of *Musa. Heredity 2 :* 101-117.

Received for publication July, 1948.

PHOSPHATE DEFICIENCY IN SOME WEST INDIAN SOILS AS REVEALED BY POT TESTS

BY

F. HARDY,

(Imperial College of Tropical Agriculture, Trinidad)

(I) Introduction

Pot experiments of various sorts, designed to reveal and approximately to assess the nutrient status of West Indies agricultural soils, have been intermittently carried out in the Chemistry Department of the College for many years, partly to provide practical exercises for students. They have included the standard Mitscherlich method for determining nutrient requirements in which Sudan Grass has mostly been used as indicator plant, as well as simple pot experiments in which increasing dosages of manure have been added to soil cultures planted with the same and other indicator plants. Among the methods tried, cigarette-tin experiments have proved very useful and expedient, particularly as a check on the results of conventional chemical soil analysis. In these experiments, tomato has proved to be especially suitable as indicator plant. Its usefulness in pot-tests, aimed particularly at determining phosphate shortage, was first demonstrated at the College by Mr. J. A. McDonald who successfully applied the test to a series of Trinidad cacao soils * and Antigua sugar-cane soils. † The tomato test was first suggested as an indicator of phosphate deficiency by L. Mayer in Germany in 1929. When grown in phosphate-deficient soils, characteristic purple colouration of the hypocotyl and the under surface of the seedling leaves and marked darkening of the green colour of the upper surface appears in a few days. Furthermore, the subsequent growth of the plant is greatly retarded so that the dry weight increase, say after 9 weeks' growth, furnishes a comparative measure of the available phosphate status of the soils under test. Thus McDonald obtained fair agreement between the yields of dry matter of tomato seedlings grown in different soils and their contents of available phosphate as determined in the laboratory by the Truog test which employs very dilute sulphuric acid as phosphate-extracting agent.

(II) The tomato seedling test applied to some soils of the Lesser Antilles

Chemical analysis of a large number of soil samples collected by us in the course of soil reconnaissance surveys in the islands of the Lesser Antilles have revealed a universal deficiency of available phosphate as determined by the Truog test. At the same, a small number of Mitscherlich pot tests have demonstrated that certain kinds of West Indies soils behave abnormally in that the results of the Truog test are not concordant with those obtained by the Mitscherlich method. Among these " abnormal " soils are Rendzina (humus-carbonate soil, derived from soft limestones and marls), ferruginous red soils and recent " fresh " volcanic ash. In order to discover if other kinds of soil behave similarly to these abnormal soils, composite samples were made up from a large number of soil survey samples representing different soil-types. These were all tested by the Truog chemical method and by the tomato seedling method. Some of the composite samples comprised soil parent materials (deep subsoils) such as may be exposed by severe soil erosion on hill-slopes. Knowledge of the nutrient status and manurial requirements of these parent materials is especially desirable in connection with schemes for land rehabilitation.

Procedure : Waxed cardboard containers (ice-cream cartons), holding 750 grams ‡ of 2 mm. sifted air-dry soil, were used. Holes were bored in the bottom and a layer of fine gravel was introduced for drainage. The soil was loosely packed on top and moistened from below by placing in a trough of water. Solutions of manures were now added in appropriate quantities and the mixtures allowed to stand for 10 days.

Tomato seeds (" Bonny Best ") were then sown. After germination, all but seven seedlings were removed. The cultures were placed in a greenhouse and watered twice daily. Notes were periodically made on the general appearance of the seedlings. The experiment was discontinued when the plants were 9 weeks old. Photographs were taken when they were 8 weeks old. The crop in each culture was dried and weighed, tops and roots separately.

Treatments : Each set of cultures included four manurial treatments, namely, (i) nitrogen alone (N), (ii) nitrogen and potash (NK), (iii) nitrogen, phosphate and potash (NPK) and (iv) double nitrogen, treble phosphate, and potash (2N3PK). The unit amounts of stand-

* A Sensitive Pot-Test for Phosphate Deficiency in Soils, J. A. McDonald, *Trop. Agriculture, Trin.*, 1933, X, pp. 108-111.

† The Sugar-Cane Soils of Antigua, F. Hardy, J. A. McDonald and G. Rodrigues, I.C.T.A., Trinidad, 1933.

‡ This amount of dry soil is about one-quarter the amount which a standard Mitscherlich enamelled iron pot will hold, and about two and-a-half times as much as an ordinary cigarette tin (50's) will hold.

ard manures used were equivalent to those employed in the Mitscherlich pot test, namely, 12½ cwt. per acre of sulphate of ammonia, 16 cwt. per acre of superphosphate and 7½ cwt. per acre of sulphate of potash. These unit quantities are relatively very large, particularly phosphate; they are intended to provide a sufficiency of the three main nutrients and to allow for possible fixation of phosphate and potash. Ammonium nitrate was actually used instead of ammonium sulphate, and sodium hydrogen phosphate instead of superphosphate, in chemically-equivalent amounts.

Observations during growth: The characteristic symptoms of phosphate-shortage described above developed within two or three weeks after germination. It was noticed, however, that *chlorotic symptoms* also appeared on many of the cultures. These were easily dispelled by adding more nitrogenous manure; they were thus obviously caused by nutrient unbalance. The chlorosis unfortunately adversely affected the yields in proportion to its severity, so that in several cases the quantitative results were vitiated. Evidently an important effect of phosphate additions to soils having marked shortage of this nutrient is greatly to increase the capacity of plants growing in them for absorbing and utilising nitrogen. This may be attributed to the marked stimulation of root development which phosphate is known to impart. On the other hand, it is also known that the uptake of nitrogen (and of potash) is diminished when the amount of available phosphate is appreciably increased.

The most severe cases of chlorosis among the tomato cultures occurred with Treatment (3), NPK. It was rarely shown with Treatment (4), 2N3PK, which included a *double* nitrogen dosage. This fact supports the contention that much greater response to nitrogenous manure may be expected from plants grown in phosphate-deficient soils when the deficiency has been corrected by appropriate treatments with suitable phosphatic manure.

Effect of liming: In four sets of cultures, the soil was limed previous to testing with tomato seedlings. The effects were somewhat variable and difficult to interpret without further investigation. In no case apparently was the liming strikingly beneficial, neither in producing greater yield nor in alleviating the symptoms of phosphate shortage. Indeed, it seemed somewhat to intensify them and slightly to encourage chlorosis.

It is well known that freshly-limed soils usually exhibit phosphate suppression immediately after soluble phosphatic manures have been added to them. The explanation usually advanced is that the added phosphate is fixed as insoluble carbonate-phosphate which is stable under the conditions of temporary and localised high alkalinity. The effect disappears in due course as the lime gradually becomes dispersed throughout the upper layer of soil and is used up in neutralising soil acids. Subsequently the phosphate is released in an easily-available form and may then produce its characteristic beneficial results.

Although finely-divided calcium carbonate was intimately mixed with the soil in our tomato cultures, perhaps not enough time was allowed for full interaction to take place, so that temporary fixation of the added phosphatic manure occurred.

(III) Description of the soils and results

Altogether, 26 composite soil samples were analysed by routine chemical methods (including the Truog test for available phosphate) and later by the tomato seedling test in cartons. The composites represented 14 different soil-types occurring in six of the Lesser Antillean islands. They included 12 samples of soil parent materials (deep subsoils). The names of the islands and soil-types and the sites where the samples were procured are:—

Island	Lithological Soil-Type	Site
(A) BARBADOS	(I) Lagoon Clay	St. George's Valley
(B) ST. VINCENT	(II) Recent Volcanic Ash	Lower slopes of Soufriere
	(III) Yellow Earth; low level	Windward coastal belt
	(IV) Yellow Earth-high level	Foothills, mainly windward
	(V) Coastal Colluvial-Alluvial	Coastal plains and valleys
(C) ST. LUCIA	(VI) Red Earth	Northern hills
	(VII) River Alluvial	Cul-de-Sac, Roseau, Dennery
(D) MONTSERRAT	(VIII) Volcanic Ash	Lower slopes of southern volcanic cones
	(IX) Terras	Elberton; Garibaldi Hill
	(X) Shoal	Olveston, Woodlands
	(XI) Brown Earth	Windward slopes of South Soufriere Hills
(E) NEVIS	(XII) Shoal	Hilly lands
(F) ST. KITTS	(XIII) Volcanic Ash (Settlements)	Sadlers, Fahies
	(XIV) Volcanic Ash (Estates)	Buckleys, Molyneux

Laboratory data showing the physical and chemical characteristics of the soils are given in Table I and the results of the tomato seedling test are set out in Table II in which yields are expressed as dry matter (grams), tops and roots, reaped at 9 weeks of age. Index letters denoting (a) absence of phosphate-shortage symptoms, (b) presence of marked or "bad" phosphate-shortage symptoms, and (c) presence of chlorotic symptoms are attached to some of the data.

The following notes refer to the different soil samples thus examined and summarise the main findings.

(A) BARBADOS: *(I) Lagoon clay; St. George's Valley* — (Sugar-cane)

Two composite soil samples were tested, namely, topsoil, 0-6 ins. depth, and parent material, 48-63 ins. The latter was also tested after liming to pH 7.2. The soil is derived from lagoon or estuarine clay overlying coral limestone. The site probably at one time comprised a mangrove swamp forming an inlet of the sea. The soil has some of the features of Hydromorphic Bog Soil, though its upper layer is mixed with calcareous hill-wash. Available phosphate contents (Truog) are very high but available (exchangeable) potash contents tend to be low. The tomato test showed no phosphate shortage and no response of the parent material to liming.

(B) ST. VINCENT: *(II) Recent Volcanic Ash; Soufriere* — (Sugar-cane, cotton)

Two composite samples were tested, topsoil 0-6 ins., and deep-seated ash, 48-72 ins. The samples were taken from Mt. Bentinck, Richmond Vale and Grand Sable Estates situated on the lower slopes of Soufriere. The ash was deposited during the 1902-03 eruptions. The soil-type is Lithosol that has suffered little

TABLE I: LABORATORY DATA FOR THE SOILS EXAMINED

Soil-type		Silt and Clay (%)	Index of Text.	Reaction (pH)	Org. matt. (%)	Total nitrogen (%)	C/N ratio	Avail. phosphate* (ppm.)	Avail. potash† (ppm.)
(A) BARBADOS									
(I) **Lagoon Clay**	Top	84	39	6.9	2.26	.105	12.5	369	**180**
	Sub	93	46	7.2	0.26	.024	6.1	406	63
(B) ST. VINCENT									
(II) **Recent Volcanic Ash**	Top	15	3	6.5	1.72	.080	13.0	67	297
	Sub	16	3	7.1	0.29	.018	9.2	**45**	**101**
(III) **Yellow Earth**	Top	20	3	6.8	1.24	.077	9.4	**41**	163
Low level	Sub	25	12	6.5	0.55	.033	9.6	**15**	245
(IV) **Ditto.**	Top	23	14	5.6	2.26	.134	9.8	**17**	286
High level	Sub	29	16	6.6	0.41	.028	8.6	**13**	231
(V) **Coastal Alluvial-**	Top	35	12	6.4	2.24	.121	10.7	181	287
Colluvial	Sub	25	5	6.9	0.55	.038	8.5	699	150
(C) ST. LUCIA									
(VI) **Red Earth**	Top	42	21	6.5	2.22	.145	8.9	**15**	193
(VII) **River Alluvial Soil**	Top	71	34	6.4	3.71	.176	12.2	**29**	**145**
	Sub	54	26	7.0	0.52	.042	7.2	**21**	**69**
(D) MONTSERRAT									
(VIII) **Volcanic Ash**	Top	22	4	6.8	1.52	.063	14.0	324	275
	Sub	20	4	7.2	0.38	.026	8.4	133	135
(IX) **Terras**	Top	44	12	6.8	2.07	.130	9.2	**47**	227
	Sub	19	2	7.3	0.16	.024	3.8	**51**	151
(X) **Shoal**	Top	40	13	6.7	2.60	.142	9.6	55	155
	Sub	11	2	6.7	0.19	.014	7.9	**30**	**95**
(XI) **Brown Earth**	Top	35	9	6.3	2.17	.120	9.5	83	226
	Sub	32	10	6.8	0.48	.033	8.4	**13**	132
(E) NEVIS									
(XII) **Shoal**	Top	42	15	6.3	2.67	.145	10.7	18	230
(F) ST. KITTS									
(XIII) **Volcanic Ash**	Top	17	3	6.0	2.72	.135	8.7	69	184
(Settlements)	Sub	12	2	6.5	0.33	.025	7.6	108	126
(XIV) **Volcanic Ash**	Top	19	3	6.4	1.78	.076	13.4	385	304
(Estates)	Sub	18	4	7.2	0.19	.023	4.9	61	160

* Truog's method: Limits of adequacy: clays 55, sands 35 p.p.m.

† Exchangeable K_2O: Limits of adequacy: clays 200, sands 130 p.p.m.

NOTE: Values in heavy type in last two columns denote deficiency in available phosphate and available potash respectively.

TABLE II: RESULTS OF TOMATO SEEDLING TEST

(A) BARBADOS

(I) Lagoon Clay; **St. George's Valley** (sugar-cane)

	Tops	Roots	Total (g)	Tops	Roots	Total (g)	Tops	Roots	Total (g)
		(1) Topsoil			(2) Subsoil			(3) Subsoil-LIMED	
(i) N	3.8	0.45	4.25 (a)	4.3	1.00	5.30 (a)	4.2	0.60	4.60 (a)
(ii) NK	4.3	0.60	4.90 (a)	6.5	0.85	7.35 (a)	4.95	0.55	5.50 (a)
(ii) NK	3.3	0.35	3.65 (c)	5.2	0.70	5.90	5.1	0.55	5.65
(iv) 2N3PK	8.3	1.45	9.75	6.6	0.75	7.35	5.7	0.55	6.25

(B) ST. VINCENT

(II) **Recent Volcanic Ash; Soufriere** (sugar-cane, cotton, arrowroot)

	Tops	Roots	Total (g)	Tops	Roots	Total (g)
		(4) Topsoil			(5) Subsoil	
(i) N	0.6	0.35	0.95 (b)	0.3	0.10	0.40 (b)
(ii) NK	0.4	0.05	0.45 (b)	0.3	0.10	0.40 (b)
(iii) NPK	5.8	0.90	6.70	4.9	1.20	6.10
(iv) 2N3PK	4.5	1.65	6.15	6.0	1.65	7.65

(III) **Yellow Earth; low level; Coastal Belt** (cotton, arrowroot)

		(6) Topsoil			(7) Subsoil	
(i) N	0.6	0.15	0.75 (b)	0.2	0.05	0.25 (b)
(ii) NK	0.5	0.10	0.60 (b)	0.2	0.05	0.25 (b)
(iii) NPK	7.4	1.53	8.95	4.5	0.75	5.25
(iv) 2N3PK	6.3	1.10	7.40	7.0	0.85	7.85

(IV) **Yellow Earth; high level; Foothills** (cotton, arrowroot)

		(8) Topsoil			(9) Subsoil	
(i) N	0.3	0.15	0.45 (b)	0.3	0.05	0.35 (b)
(ii) NK	0.3	0.15	0.45 (b)	0.3	0.05	0.35 (b)
(iii) NPK	5.4	1.15	6.55	6.8	3.00	9.80
(iv) 2N3PK	8.0	0.70	8.70	8.3	1.85	10.15

(V) **Coastal Alluvial—Colluvial Soil; Leeward Flats mainly;** (cotton, sugar-cane)

		(10) Topsoil			(11) Subsoil	
(i) N	5.5	0.65	6.15 (a)	4.6	0.55	5.15 (a)
(ii) NK	5.4	0.65	6.05 (a)	5.5	0.85	6.35 (a)
(iii) NPK	6.5	0.70	7.25 (c)	4.6	0.75	5.35 (c)
(iv) 2N3PK	7.2	1.10	8.30	6.8	1.20	8.00

(C) ST. LUCIA

(VI) **Red Earth; Peasants Holdings, North;** (food crops mainly)

	Tops	Roots	Total (g)	Tops	Roots	Total (g)
		(12) Topsoil			(13) Topsoil-LIMED	
(i) N	3.5	0.50	4.00	0.7	0.10	0.80 (b)
(ii) NK	3.5	0.75	4.25	0.7	0.15	0.85 (b)
(iii) NPK	6.6	1.35	7.95	7.4	1.90	9.30
(iv) 2N3PK	8.3	1.40	9.70	9.9	1.50	11.40

(VII) **River Alluvial Soil;** (Roseau, Cul-de-Sac, Dennery)

		(14) Topsoil			(15) Topsoil-LIMED	
(i) N	0.4	0.15	0.55 (b)	0.55	0.10	0.65 (b)
(ii) NK	0.4	0.15	0.55 (b)	0.4	0.05	0.45 (b)
(iii) NPK	5.3	0.80	6.10 (c)	2.1	0.20	2.30 (c)
(iv) 2N3PK	5.2	0.60	5.80	2.6	0.30	2.90 (c)
		(16) Subsoil			(17) Subsoil-LIMED	
(i) N	0.2	0.05	0.25 (b)	0.5	0.10	0.60 (b)
(ii) NK	0.2	0.15	0.35 (b)	0.4	0.10	0.50 (b)
(iii) NPK	5.25	0.65	5.90	5.45	0.45	5.90 (c)
(iv) 2N3PK	6.4	0.95	7.35	7.4	0.95	8.35 (c)

TABLE II (Cont'd)

(D) MONTSERRAT

(VIII) Volcanic Ash;

	Tops	Roots	Total (g)		Tops	Roots	Total (g)	
		(18) Topsoil				(19) Subsoil		
(i) N	3.4	0.55	3.95	(a)	3 8	0.40	4.20	(a)
(ii) NK	1.0	0 25	1.25	(c)	2.8	0 55	3.35	(a)
(iii) NPK	1.3	0.25	1.55	(c)	1 9	0.30	2.20	(c)
(iv) 2N3PK	3.1	0.40	3.50	(c)	3.6	0.60	4.20	(c)

(IX) Terras;

		(20) Topsoil				(21) Subsoil		
(i) N	1.7	0.20	1.90		0 2	0.05	0.25	(b)
(ii) NK	1.45	0.15	1.60		0 3	0 05	0.35	(b)
(iii) NPK	3.15	0.30	3.45	(c)	6 0	1.40	7.40	
(iv) 2N3PK	7.45	0.50	7.95		5 8	0.85	6.65	

(X) Shoal;

		(22) Topsoil				(23) Subsoil		
(i) N	3.7	0.55	4.25	(a)	1.1	0.25	1.35	(b)
(ii) NK	3.8	0 55	4.35	(a)	0 35	0 06	0.41	(b)
(iii) NPK	5.1	0.75	5.85	(c)	4 0	1.25	5.25	
(iv) 2N3PK	3.7	0.50	4.20	(c)	6.7	1.80	8.50	

(XI) Brown Earth;

		(24) Topsoil				(25) Subsoil		
(i) N	0.5	0.10	0.60	(b)	0 2	0.02	0.22	(b)
(ii) NK	1.3	0.25	1.55	(b)	0 2	0.02	0.22	(b)
(iii) NPK	4.9	0.60	5.50		4.75	0 67	5.42	
(iv) 2N3PK	6.4	1.05	7.45		6.8	0.90	7.70	

(E) NEVIS

(XII) Shoal;

	Tops	Roots	Total (g)	
		(26) Topsoil		
(i) N	0.5	0.03	0.53	(b)
(ii) NK	0.3	0.02	0.32	(b)
(iii) NPK	3.35	0.25	3.60	(c)
(iv) 2N3PK	5.7	0.45	6.15	

(F) ST. KITTS

(XIII) Volcanic Ash; Peasant Settlements;

	Tops	Roots	Total (g)		Tops	Roots	Total (g)	
		(27) Topsoil				(28) Subsoil		
(i) N	0.45	0.20	0.65	(b)	0 2	0.15	0.35	(b)
(ii) NK	0 95	0.40	1.35	(b)	0 4	0.20	0.60	(b)
(iii) NPK	5.0	1.35	6.35	(c)	3.8	0 80	4.60	(c)
(iv) 2N3PK	5.0	0.95	5.95	(c)	3.05	1.15	4.20	(c)

(XIV) Volcanic Ash; Sugar Estates;

		(29) Topsoil				(30) Subsoil		
(i) N	5.5	0.75	6.25	(a)	0.25	0.05	0.30	(b)
(ii) NK	6.35	0.95	7.30	(a)	0.30	0.05	0.35	(b)
(iii) NPK	3.85	0.80	4.65	(c)	5.1	0.80	5.90	(c)
(iv) 2N3PK	5.6	0.90	6.50	(c)	6.1	1.15	7.25	

weathering. Its component particles are partly vitrified and scoriaceous. Available phosphate appears to be just about adequate by the Truog test but potash is deficient in the deep-seated material though not in the surface soil. The tomato test showed marked phosphate shortage, so that the soil is abnormal in that the Truog test does not give low values. Soufriere Volcanic Ash subsoil (4 ft. depth) had previously been tested by a simple flower-pot method * and found to give hardly any crop of Sudan Grass except when treated with phosphatic manure and with nitrogenous manure (sulphate of ammonia ; raw humus) since the material naturally contained little organic matter. Addition of potash manure proved not to give much extra yield.

Hence, in spite of its high Truog value, St. Vincent Volcanic Ash Soil would be expected to respond greatly to relatively large dressings of phosphatic manure when accompanied by nitrogenous manure, either artificial or organic. Nitrogenous manure in the *absence of phosphate* would not be expected to confer maximum benefit.

(B) ST. VINCENT : *(III) Yellow Earth ; low level* — (arrowroot, cotton)

Here again, topsoil, 0-6 ins. and parent material, 38-60 ins., were tested. The samples were taken mainly from windward coastal estates (Diamond, Argyll, Spring, Sans Souci). The soil is considered to be an immature Calcimorphic type. Its component felspar grains have given rise to pseudomorphs of some white kaolinic mineral. Available phosphate contents are characteristically very low in this soil-type, generally less than 10 p.p.m. Available potash is variable but usually quite high.

The tomato test agreed with the Truog test in showing marked phosphate shortage. Yellow Earth subsoil (48-72 ins.) had previously been tested by the standard Mitscherlich method, † as well as by simpler pot-tests, in which the effects of phosphate and of potash on the utilisation of increasing dosages of nitrogen were separately determined. Unfortunately, through an accident, the Mitscherlich experiment failed, but the other experiments showed conclusively that increasingly large yields of Sudan Grass are given by multiple dosages of nitrogenous manure, provided an adequate amount of phosphate is also applied. Potash did not give this result, although, in the presence of phosphate and nitrogen, it produced some additional growth.

Where Yellow Earth topsoil contains an adequate amount of nitrogenous organic matter, the application of soluble phosphatic manure alone may be expected to give results, but where the topsoil is deficient in nitrogen, or where the soil is deeply eroded so that the parent material is exposed, both nitrogenous and phosphatic manures are needed to give high yields, although maximum yields could not be expected even then unless potash manures in appropriate quantity were also judiciously employed. The quantities of manures required for optimum economic results for any particular crop would necessitate the prosecution of carefully-planned field experiments for their accurate determination. The chief value of chemical soil analysis and pot-tests depends on the fact that they provide a reliable guide to the kinds and quantities of manures that should be included in a full-scale manurial experiment in the field. Too often in the past the quantities have been nominal and merely guessed, or their selection based on the results obtained with temperate crops grown in entirely different types of soil.

(B) ST. VINCENT : *(IV) Yellow Earth ; high level* (arrowroot, cotton)

As before, topsoil 0-6 ins, and parent material, 48-72 ins., were tested. The results obtained did not differ materially from those given by the low level samples. The places where the high level soils were collected (Carriere, Lauders, etc.) were mainly at 700-1,000 ft. elevation. The composite topsoil contained more organic matter and nitrogen than the comparable low-level soil, but its available phosphate content was somewhat less. This is a characteristic difference between the two soils, implying a greater need for phosphate manure in the higher lands. The tomato test showed phosphate shortage very clearly in both topsoil and parent material.

(B) ST. VINCENT : *(V) Coastal Colluvial-Alluvial soil* (arrowroot, cotton, sugarcane)

The topsoil sample, 0-6 ins., and the deeper-seated parent material, 40-56 ins., are both remarkable in that they contain relatively large amounts of available phosphate and showed no phosphate shortage by the tomato test. The samples were taken from coastal flats at Peruvian Vale, Diamond, Arnos Vale and Kingstown (Cotton Station), and from the colluvial valley bottoms at Cane Grove and Peters' Hope on the leeward coast. They included no samples from Camden Park. The materials doubtless contain much nutrient-rich hill-wash ; they are among the most naturally-fertile of the St. Vincent present-day agricultural soils though doubtless very variable.

* Subsoil Fertility of Eroded Volcanic Ash in St. Vincent, B.W.I., F. Hardy and E. G. Cripps, *Trop. Agriculture, Trin.*, 1944, XXX, pp. 30-39.

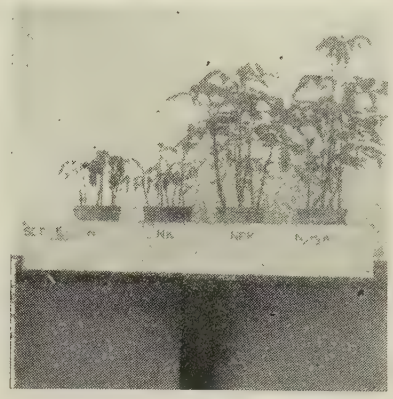
† Ibid.

RESULTS OF TOMATO SEEDLING TEST FOR PHOSPHATE SHORTAGE

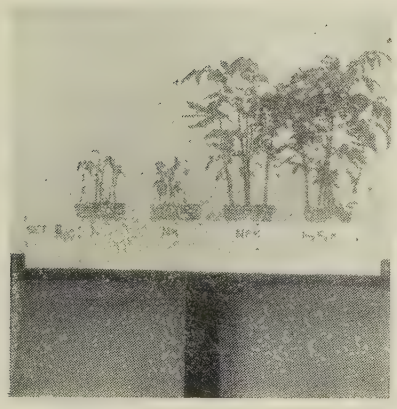
TOPSOIL CULTURES

Age : 8 Weeks

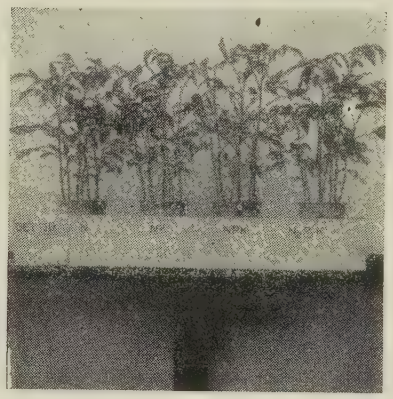
RECENT ASH



YELLOW EARTH
(Low level)

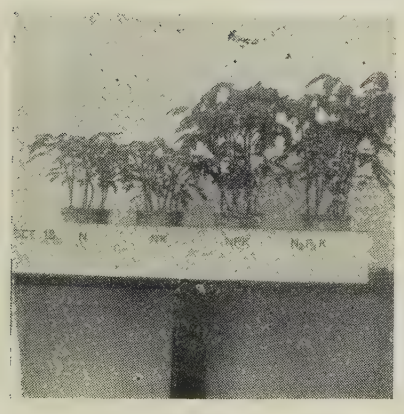


YELLOW EARTH
((High level)



COASTAL/ALLUVIUM

ST. VINCENT



RED EARTH

RIVER ALLUVIUM

ST. LUCIA

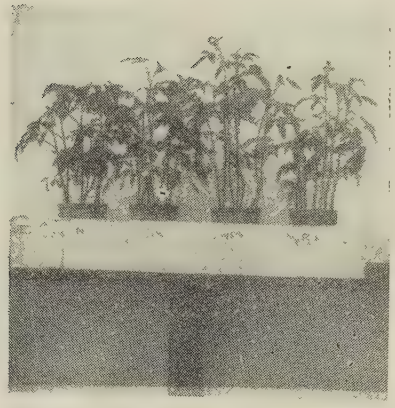
RESULTS OF TOMATO SEEDLING TEST FOR PHOSPHATE SHORTAGE

TOPSOIL CULTURES

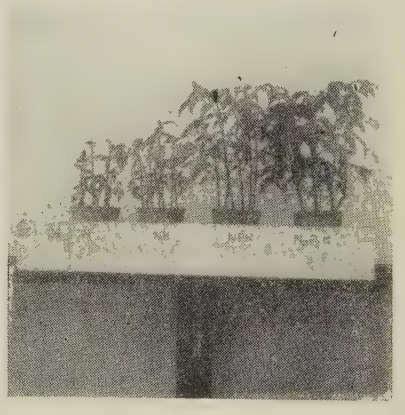
Age : 8 Weeks

LITHOSOL

TERRAS

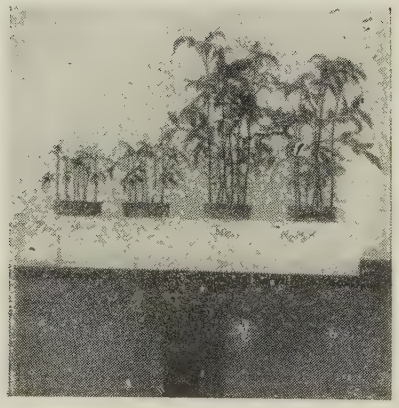


SHOAL



BROWN EARTH

MONTSERRAT



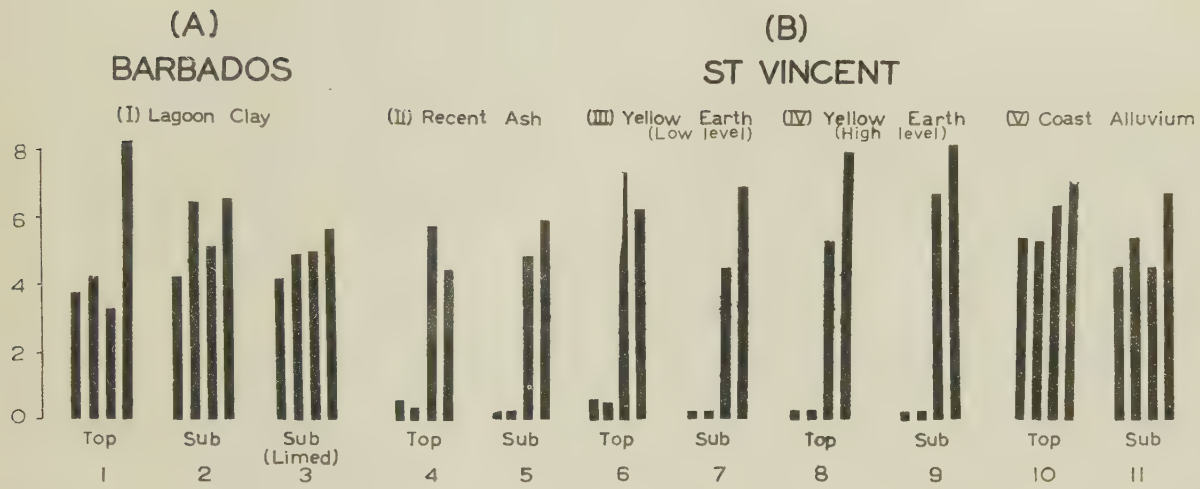
LITHOSOL
(Peasants)

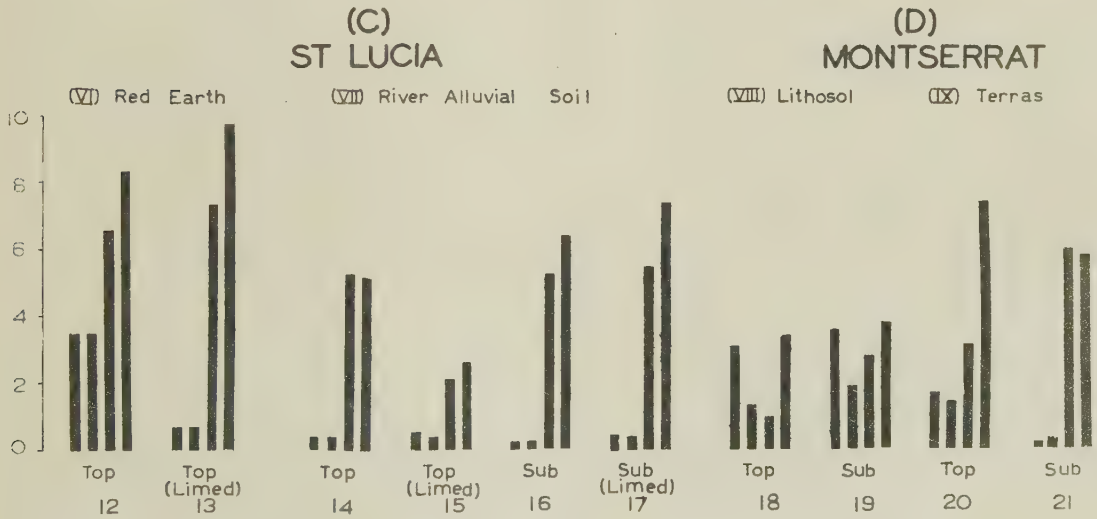
LITHOSOL
(Estates)

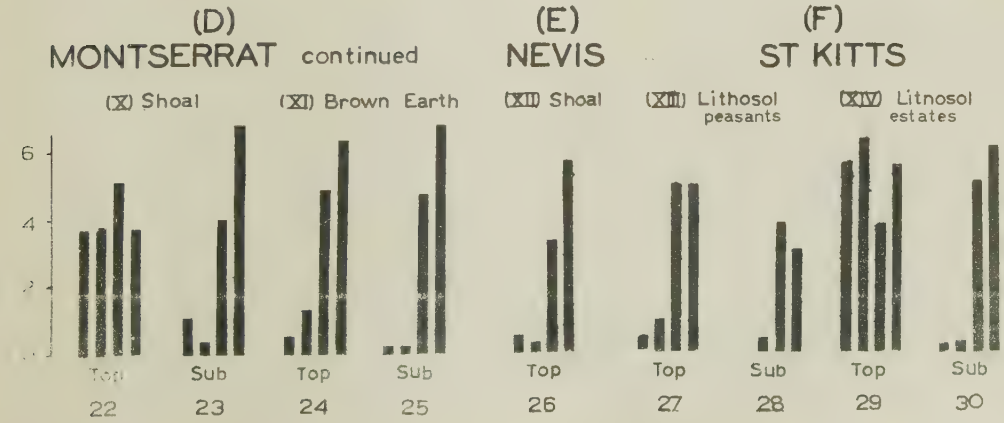
ST. KITTS

RESULTS OF TOMATO SEEDLING TEST

Weights of dry matter produced (grams)







(C) ST. LUCIA : *(VI) Red Earth ; peasants' holdings, northern hills* (food crops mainly)

Only topsoil, 0-6 ins., was included in the reconnaissance soil survey samples, so that this alone was tested. The samples were mostly collected from the Morne Fortuné area near Castries, though some came from the red lands of the Grand Riviere and Postlethwaite Districts. This is the only sample of Red Earth that was examined. The type is widespread in St. Lucia and also in Grenada and in the French Islands. It is highly acid and phosphate-deficient. It is also an active phosphate-fixer. The tomato test applied to the St. Lucia sample showed distinct phosphate shortage. Liming seemed to have greatly depressed phosphate availability as gauged by the pot-test.

(C) ST. LUCIA : *(VII) River Alluvial Soil : Cul-de-Sac., Roseau, Dennery Estates* (sugar-cane)

Topsoil, 0-6 ins., and parent material, 42-72 ins., both unlimed and limed, were tested. The composites were made up of samples collected from 3 profiles at Cul-de-Sac, 3 at Roseau, and 3 at Dennery sugar estates. The soils are mostly orange-mottled, acid in reaction and markedly deficient in available phosphate. They are also somewhat deficient in available potash. The tomato test showed large phosphate shortage in both topsoil and deep subsoil. Liming seemed not to have conferred any benefit, but chlorosis greatly diminished the yields of some of the cultures so that the results are inconclusive.

(D) MONTSERRAT : *(VIII) Volcanic Ash ; lower slopes of southern volcanic cones* (cotton, limes)

Topsoil, 0-6 ins., and deep-seated ash, 32-54 ins., were separately tested. They were collected from the lower slopes of St. George's Hill, Soufriere Hills and South Soufriere Hill. Both soils consist of practically unweathered material. They are neutral in reaction and gave very high Truog values for available phosphate. Available potash is rather low in the deep material. Both are deficient in organic nitrogen and their carbon-nitrogen ratio is especially high in the topsoil. The tomato test showed little phosphate shortage in contrast to the comparable St. Vincent Recent Volcanic Ash. This result is contrary to those obtained in certain field experiments in which cotton, growing on Volcanic Ash Soil in Montserrat, showed a marked response to superphosphate manure. *

The actual sample tested by the tomato seedling method contained an unusually large amount of available phosphate (324 p.p.m. as against an average for the type of 220 p.p.m.) and this may account for the unexpected result. The cultures that received nitrogenous manure all developed marked chlorosis which greatly reduced the yields. Evidently this soil is very deficient in available nitrogen ; hence the addition of a large amount of phosphatic manure suppressed the uptake of nitrogen even from the double dosage given in Treatment (4).

(D) MONTSERRAT : *(IX) Terras ; Elberton* (limes, cotton)

Topsoil, 0-6 ins., and partly cemented volcanic ash (terras ; incipient hardpan), 30-60 ins., were collected mainly from Elberton Estate on the lower slopes of Garibaldi Hill. Available phosphate content is on the borderline of adequacy by conventional standards, and available potash just adequate. The samples appear to be normal, average materials. The tomato test showed considerable phosphate shortage as well as a slight nitrogen shortage as indicated by a tendency to develop chlorosis.

(D) MONTSERRAT : *(X) Shoal ; north-west coastal belt ;*

Topsoil, 0-6 ins., and well-cemented volcanic ash or fine agglomerate (Shoal ; hardpan), 20-30 ins., were collected mainly from Olveston, Woodlands and Sweeneys Estates in the central and north-western coastal belt of the Island. Available phosphate and available potash are generally deficient in this soil-type, especially in the shoal itself (hardpan). The topsoil composite unforunately contained one subsample having an unusually high phosphate content which raised the level of this nutrient above the average value 30 p.p.m., so that the tomato test showed only a slight phosphate shortage. The deeper subsoil sample was normal and showed marked phosphate shortage by the pot-test. Chlorosis developed in the topsoil cultures that received a limited amount of nitrogen. Typical shoal soil in Montserrat has given marked response to superphosphate manure in recent field experiments with cotton. †

(D) MONTSERRAT : *(XI) Brown Earth ; windward slopes, South Soufriere Hills* (cotton, tomato)

Topsoil, 0-6 ins., and parent material, 20-40 ins., of this important Montserrat soil-type were collected mainly from the misty windward slopes of Soufriere Hills and from the hill-divide at Rileys. Although the composite contained one abnormal sample rich in phosphate, the type, though variable, tends to be deficient in

* The significance of Carbon-Nitrogen Ration in Soils Growing Cotton ; (III) Nitrate Fluctuations in Relation to Planting Date and Soil Manurial Requirements in the British West Indies, F. Hardy, *Trop. Agriculture, Trin.*, 1946, XXIII, pp. 201-211.

† Ibid.

available phosphate and on the borderline for potash. The tomato test showed definite phosphate deficiency symptoms for both topsoil and parent material, but no chlorosis. Field manurial experiments on Brown Earth growing cotton have given variable but definite indications of benefit likely to accrue from manuring with superphosphate. The tomato crop, grown in this soil, should respond markedly to phosphatic manures.

(E) NEVIS : *(XII) Shoal; hilly lands* (cotton)

Topsoil, 0-6 ins., alone was tested. No hard shoal samples were collected. The sample was composite taken mostly from the northern hilly part of the Island (Spring Hill, Nisbetts). The soil is a stiff clay having low available phosphate content and variable, though usually rather low, available potash content. The tomato test showed large phosphate shortage in the topsoil. Chlorosis developed in the NPK treatment (No. 3), although the organic matter content was quite high.

Field manurial experiments on cotton growing Shoal Soil deficient in available phosphate, have given marked response to superphosphate manure in an experiment carried out in 1941. *

(F) ST. KITTS : *(XIV) Volcanic Ash; windward slopes, mainly* (sugar-cane)

Composite soil samples were taken from Land Settlement areas that once had been sugar-cane estates (Sadlers, Fahies), and from sugar-cane estates (Buckleys, Molyneux). In each case topsoils, 0-6 ins., and deep-seated subsoil samples were taken. The St. Kitts Volcanic Ash Lithosol is mostly stony or cindery below and sandy or loamy on top. It is deficient in available phosphate in the topsoil, as gauged by the tomato test, though not necessarily so when examined by the Truog chemical method. This has been found to be a general feature of Lithosol in the British West Indies volcanic islands. Available potash, on the other hand, is variable but usually rather low in amount.

The tomato test gave characteristic results with the Land Settlement samples, but the topsoil of the Estates lands proved to have a very high available phosphate content; its Truog value was also extremely high. The high phosphate status of this soil may perhaps be explained by the fact that superphosphate manure had been applied to the land regularly before 1943, though not since that year. The subsoil, like the Settlements subsoil, showed marked phosphate shortage. All four soil samples showed strong chlorosis symptoms, especially the Estates soils which are lacking organic matter. Chlorosis was more marked here than in any other soil in the whole series examined.

(IV) Summary

(1) A series of 24 samples of topsoil and deep subsoil (soil parent material), representative of 13 important soil-types occurring in the Volcanic Islands of the Lesser Antilles and two from Barbados, were examined for available phosphate shortage by a simple pot-test with tomato as indicator plant.

(2) Routine laboratory analyses showed that most of the samples were deficient in available phosphate by the Truog test and the pot-test gave corresponding results. Others were abnormal in that they showed a high Truog value and yet they showed phosphate shortage by the pot-test.

(3) In a few cases the effect of liming was also tested but the results were erratic, probably because sufficient time had not been allowed for the lime to act.

(4) The results on the whole demonstrate a remarkable deficiency of available phosphate in West Indian Volcanic Soils and a marked response to generous dressings of phosphatic manure, provided abundant nitrogen is also present in available form or added as manure.

Received for publication, April, 1947.

* Ibid.

SOME RECENT DEVELOPMENTS IN FROGHOPPER CONTROL

BY

F. H. B. Blackburn
(Caroni Ltd., Trinidad).

Introduction

The froghopper, *Tomaspis saccharina* Dist., has long been the most serious pest of sugar cane in Trinidad. Following recognition of its responsibility for the well known blight of sugar cane, (1), many investigations were carried out with the object of finding an economic control method. The life history and habits of the froghopper were described in detail in 1921 (2), but the problem of its control proved so difficult that, as late as 1942, no satisfactory method had been devised (3). Cultivation and manuring, biological control and the planting of resistant varieties had been tried with little success; cyanogas, applied by hand duster against the nymph, and pyrethrum, by a drift dusting technique against the adult, had been the most successful insecticides but their use had been abandoned by most estates. In 1946, when D.D.T., B.H.C. (gamma-hexachloro-cyclohexane or 666) and Sabadilla proved more effective than pyrethrum, it was felt that, at last, an economic solution had been found (4, 5). The purpose of this paper is to describe experiments and observations which, it is believed, lead to the conclusion that the froghopper can best be controlled by the destruction of either the nymph or the egg.

Life History

Each female froghopper is capable of laying 40 – 100 eggs in the top 2 inches of soil in and around the cane stool; few eggs are to be found either at greater depths or in the cane trash (6).

Fourteen or more days later, some of the eggs hatch into nymphs which, after undergoing five moults in 5 – 7 weeks, emerge as adult insects; the length of one life cycle is thus about two months. Other eggs, in increasing numbers towards the end of the wet season, have a marked tendency to go into diapause. They allow the carry over of the pest from one wet season to another for, on hatching with the onset of the rains of the following year, they give rise to first brood nymphs; first brood adults lay eggs which hatch into second brood nymphs, and so on throughout the froghopper season (June – November). Typical graphs recording the annual adult froghopper population show 3 or 4 maxima, each representing the peak emergence of a brood; occasionally, irregular hatching caused by variations in the climate — a wet dry-season or a dry wet-season — makes it difficult to divide the outbreaks into definite broods.

Nymphs excrete and live in masses of froth or spittle; they, too, are confined to the soil around the cane stools. Adults spend the heat of the day in leaf funnels, coming out towards evening to feed on exposed leaf blades.

Froghopper Damage

Damage is caused by the feeding activities of both nymphs and adults. Nymphs eat cane roots and give rise to occasional blight only; adults, however, can cause such widespread and severe damage that "Trinidad ..... has the unenviable distinction of possessing what may be regarded as the second worst insect pest in the world ... the froghopper is responsible in certain years for the loss of a greater proportion of a single country's production of a particular commodity than any other insect with the exception of the Cotton Boll Weevil" (6, p. 5).

A full description of the aetiology of froghopper blight has been given by Withycombe (7). The adults when feeding inject saliva which causes the breakdown of plant tissue for considerable distances along the leaves. At best, this destruction brings about a check in growth with consequent shortening of internodes; at worst, the death of the affected plants.

Recovery depends not only on the severity of the froghopper attack but also on the state of health of the cane root system, for loss of leaf area decreases the rate of root production and " .... quite a considerable acreage of cane in Trinidad, especially on the heavy clay soils, is on the verge of root atrophy in the wet season even in the absence of froghopper" (6, p. 7).

When recovery is poor first ratoons and — in exceptional cases — fields of plant cane are ploughed up; the financial loss is thus very high.

Investigations

Drift Dusting

The drift dusting technique, using BHC and DDT, was given an extended field trial at Caroni in 1947. Clouds of dust generated by Messinger dusters attached to the "power take off" of Caterpillar tractors were liberated from the eastern (windward) field traces, whence they drifted through froghopper infested canes before the gentle yet steady breeze which usually blows towards evening and during the night. At that time of day the adults, against which the dusts were liberated, are most active and therefore most vulnerable. 30 lbs. per acre of either

Agrocide 3 (5% BHC) or the less frequently used 6% DDT-ground limestone mixture gave excellent control for distances of 250 to 350 ft. from the windward traces; they were much less effective further to leeward. The eastern halves of dusted fields remained green while the western halves became heavily blighted, for many are 600 to 700 ft. wide. This effect is illustrated by the data recorded in Table 1.

TABLE I

A comparison of the effect of drift dusting on the adult froghopper population in the east, centre and west of field number Frederick 37.

Date	EAST		CENTRE		WEST		
	Before dusting	After dusting	Before dusting	After dusting	Before dusting	After dusting	
July 10	14		13		19		1st Dusting
,, 11		0		5		9	
Aug. 3	8		11		12		2nd Dusting
,, 4		1		5		7	
,, 25	11		20		20		3rd Dusting
,, 26		0		4		14	
Sept. 1	17		22		39		4th Dusting
,, 2		0		6		18	
,, 9	17		16		27		5th Dusting
,, 10		1		4		12	
,, 16	16		25		26		6th Dusting
,, 17		0		4		4	
,, 23	8		14		17		7th Dusting
,, 25		0		0		9	
Average after dusting		0		4		10	

Froghopper populations were assessed by counting the adults present in eight cane shoots chosen at random in each of five locations (north, south, east, west and centre) in each field. The figures recorded in Table 1 for field number Frederick 37 show that it was usual, after dusting, to find the shoots examined in the east to be free from froghopper, those in the centre to have an average total of four adults; those in the west, ten. By cutting special north-south traces, the western part of wide fields could be brought within effective range, but this would be done only as a last resort for it entails the conversion of considerable areas of arable land into non-productive traces. Similarly it would be much too expensive to reform the whole area into long, narrow fields, with their main axes running in a north-south direction.

Because of the uncertain onset of the rains in 1947, the emergence of the first brood was protracted and gave rise to an adult population which stayed for long periods at a relatively low level instead of following the more usual brood pattern. There can be little doubt that, to prevent damage from such an unusual outbreak, it would be necessary to dust at a much lower critical figure than that used at Caroni; further, there can be little doubt that, with experience, the observers and operators would become more efficient. Nevertheless, the inability of the equipment on trial to control froghoppers in the more remote parts of infested fields over-rode any other consideration; drift dusting was abandoned and other methods of applying the new insecticides were sought.

Experiments with T.I.F.A.

In late 1947, a series of experiments was carried out in which the insecticides were dissolved in liquids and applied as fogs by the Todd Insecticidal Fog Applicator (T.I.F.A.). It was felt that such fogs might penetrate the fields for considerable distances and leave more weather-resistant deposits on the cane leaves.

T.I.F.A. employs a novel principle: a solution of insecticide in usually an oil base is ejected as particles of variable but colloidal size as a fog. The fog is produced by passing the liquid under pressure into a hot air blast: its temperature at the distributor head is 900 – 1,100° F. Droplets containing the dissolved insecticide are deposited

on foliage to the extent of penetration by the fog.

The relative merits of various oil bases, most of which contained 5% DDT, were assessed by comparing the froghopper counts taken before and after "fogging". These counts recorded the number of adults found in the leaf axils of single cane shoots, selected at 20′ intervals along E-W traverses, the traverses themselves being 150′ apart in a N-S direction. Check counts of the experimental fields were made on each of the five days preceding "fogging": thereby the effect of the state of the brood—whether emerging or declining—on the froghopper population could be taken into account. In "fogging", as in dusting, advantage was taken of the very light easterly breeze which arises towards dusk in Trinidad. The insecticide was released from the eastern trace—occasionally the northern trace also, if the wind veered to the N.E.—and, with the help of the breeze, drifted across the field. It was anticipated that each impregnated base would be effective for a distance from the eastern trace proportional to the penetrated power of the fog produced and that froghopper counts would give an accurate figure of such penetration.

Each of the bases tried, including the two gammexane formulations L.G. 140 and Y.F. 986, was emitted as a dense fog which penetrated the cane for only 40′ to 60′ (2 to 3 cane beds) and then rose into the air and floated away as a cloud. Typical froghopper counts, which confirmed these observations,, are recorded in Table 2; they show that control was limited to 40-60ft.

TABLE 2.

The depth of effective penetration by T.I.F.A.—generated fogs.

Counts of individual stalks taken at 20′	5% D.D.T. in Diesel Oil				5% D.D.T. in No. 1 Pool Oil				5% D.D.T. in Gas Oil				
	Traverse (150′ apart)			Depth of effective penetration	Traverses (150′ apart)			Depth of effective penetration	Traverses (150′ apart)				Depth of effective penetration
	1st	*2nd*	*3rd*		*1st*	*2nd*	*3rd*		*1st*	*2nd*	*3rd*	*4th*	
1. On day of fogging	1	0	2		1	0	1		1	0	2	1	
	2	3	3		2	0	3		2	3	1	1	
	0	1	0		1	2	2		0	4	3	1	
	2	2	1		1	1	2		3	5	2	2	
	3	3	2		3	3	4		0	2	4	3	
	0	1	1		2	3	1		3	3	0	1	
2. Two days after fogging	0	0	0	40′	0	0	0	40′ – 60′	1	0	0	1	
	0	0	0		1	0	0		1	0	0	1	
	1	3	0		0	0	2		2	0	0	2	
	3	1	1		2	1	1		1	1	1	0	
	2	0	1		1	0	3		0	1	2	1	
	0	1	2		3	2	1		1	1	0	1	
3. Four days after fogging	2	4	5		2	1	0		0	0	0	0	40′ – 60′
	2	2	2		2	0	0		0	2	0	0	
	3	0	2		0	2	1		0	1	0	1	
	4	2	4		1	1	3		0	3	2	1	
	1	3	0		6	1	2		3	0	1	2	
	0	6	2		1	1	2		1	1	2	2	
4. Five days after fogging									1	0	2	0	40′ – 60′
									0	0	1	0	
									0	1	0	0	
									2	2	0	1	
									2	2	1	2	
									3	4	1	0	

Recent experience in the thorn scrub of Uganda shows that T.I.F.A. generated fogs might be expected to give 100% kill of the tsetse fly (*Glossina palpalis*) at distances up to 400 yards from the machine (8). It must be concluded that cane foliage is too dense to allow similar successful penetration.

Experiments on the application of insecticides by helicopter

Since DDT and BHC fogs and dusts, applied from the ground, had proved effective for short but inadequate distances from the windward traces, trials were carried out in 1948 to

determine the value of these insecticides when distributed more evenly by a small Bell helicopter. The trials have aroused considerable interest (9) and will be described in greater detail.

The helicopter

The helicopter proved highly manoeuvrable and was able to land at most derrick sites. Its small load carrying capacity (400 lbs. insecticide) was offset by a low fuel consumption of about 10 gallons per flying hour. The time taken to re-load was only 45 seconds.

Time of application

Dusting cannot be carried out effectively under high or gusty wind conditions: such generally occur in Trinidad from shortly after dawn until shortly before sunset. At first, then, in order to avoid night flying, routine and experimental dustings were conducted in the morning (5.30 a.m. to 8.00 a.m.) and late afternoon. Frequently the later dusting was cancelled, the wind being quite high even at dusk.

Insecticides used

The following insecticides were available for use:

10% DDT Agrocide 10 (50% BHC) Agrocide 3 (5% BHC)	received in 1948
50% DDT Agrocide 3 (5% BHC)	received in 1947

Rates of application

In order to take full advantage of the downward thrust of air from the rotor, perhaps causing insecticide to be forced into the leaf funnels in which adult froghoppers rest by day and, less probably, on or into the spittle masses, the helicopter was flown at the low speed of 20 m.p.h. and at cane top height. Under these conditions swath width was about 35 ft. and rate of application varied only with the density of the insecticide and with slot size, *i.e.*, the size of the opening in the plate fitted immediately above the hopper gate through which, when the gate is open, an impeller pushes insecticide into the air current caused by the engine fan.

On the assumption that a larger area could be dusted in unit time by using a small slot and the more concentrated insecticides, plates were cut to allow applications of 25 – 30 lbs. per acre of 5% material and 10 – 15 lbs. per acre for 10% material, the rate for 5% material being that used in routine drift dusting.

Preliminary trials

From past experience it was known that dusting with Agrocide 3 under optimum conditions would cause an excellent adult kill, the field drains being partially filled with dead froghoppers when examined on the following morning. Therefore in these preliminary experiments, which were carried out to determine the broad principles to be followed in the routine application of dusts by helicopter, it was unnecessary to use an elaborate counting technique; provided that the quantities and methods were correct, the kill would approach 100%. It was enough to use the routine method of Caroni Limited, *i.e.*, to classify the population density as mark 1, a few localised froghoppers; mark 2, a light general infestation; and mark 3, a heavy general infestation (more than two per stem).

(i) The inefficiency of dusts applied in the morning

In checking the results of morning dusting it was found that, following treatments which varied in weight and composition between 9 – 30 lbs. of 10% DDT and 33 lbs. Agrocide 3 (5% BHC) per acre, the adult population remained, for three days at least, at mark 3. Moreover, few dead froghoppers were to be found in treated fields 24 hours after dusting. Afternoon applications gave more encouraging results; 10% DDT was again ineffective but Agrocide 3, at 30 lbs. per acre, caused 100% adult mortality.

The probable interpretation of these results is that Agrocide 3, applied in the morning, adequately covered the foliage without penetrating the leaf funnels; further, the air disturbance caused by the rotor was insufficient to rouse the froghoppers, which remained dormant and protected until late afternoon, by which time the daily showers had washed away most of the insecticide. Whereas late afternoon dustings were effective because they coincided with the maximum activity of the adult froghoppers; there was no time lag during which the insecticide could be washed away. On the basis of these preliminary trials morning dusting was abandoned.

(ii) The importance of the diluent

It was noticed that Agrocide 3 (1948) did not lie as well as Agrocide 3 (1947), the diluent used in the 1948 product (largely China clay) being much "lighter" than that used in the 1947 product (largely fuller's earth); the poor lie was reflected in a patchy kill, resembling that caused by dusting in a high wind. The best lie was given by the most dense of all — Agrocide 10 diluted to 5% BHC with 100 – mesh ground limestone. "Lightest" was the diluent of the 10% DDT, a micaceous clay, Fo. 281, 14% of which consisted of particles less than 1 micron in diameter: this material fluffed up very badly.

Experiments have shown that as little as 0.8 lbs. DDT per acre will "reduce froghopper populations of from 30 to 50 adults per stool to a level at which economic injury to sugar cane does not take place" (4); therefore the inability of the 10% DDT appreciably to reduce the froghopper population was most unexpected. The results of chemical analysis and biological tests indicated that the DDT had not lost its toxicity in any way; the inference is that its inefficacy in these experiments was probably due to the unsuitable micaceous clay diluent. The results of later experiments confirmed this conclusion; when 50% DDT was diluted to 5% with 100 – mesh limestone — a suitable diluent — and applied at 30 lbs. per acre in the late afternoon, the kill was indistinguishable from that achieved by similar applications of BHC. (See figs. 2 and 3).

Agrocide 3 costs 13½ cents per lb. whereas 5% BHC, prepared by diluting Agrocide 10 (50% BHC) with ground limestone, costs 3 – 4 cents per lb.; similar price ratios apply to DDT formulations. For our purposes, then, the problem was reduced to little more than academic importance; ground limestone is produced locally, does not carry heavy freight charges and is therefore not only the most suitable diluent but also the cheapest. Nevertheless, it is clear that qualities which are desirable in dusts to be liberated from the ground are not necessarly of similar value when the dusts are dropped from the air. With more use being made of helicopters and aeroplanes in agricultural operations, this aspect of the composition of insecticides merits more attention.

(iii) Variations in the rate of application

Since insecticide had not been forced into the leaf funnels by the down-thrust of air from the rotor, which is inversely related to the ground speed of the helicopter, it was no longer necessary to dust very slowly. It became possible to determine the efficacy of smaller dosages of Agrocide 3 by applying them at greater speeds, using those slots which had given 30 lbs. per acre at 20 m.p.h. Under favourable conditions, it was found that applications of 26 lbs. per acre were satisfactory; 20 – 24 lbs. unsatisfactory. When, in routine operations, applications occasionally fell below this level, the kill was poor, as could have been predicted.

It was next determined whether a larger acreage could be covered in unit time by applying 13 lbs. per acre of 10% BHC instead of 26 lbs. per acre of the 5% material. Agrocide 10, diluted to 10% BHC with ground limestone, was released through those slots which had given a rate of 10 lbs. per acre with 10% DDT but, because of its more dense diluent, the rate actually applied was 21 lbs. per acre. The result — a patchy kill — must be attributed to uneven coverage, for 2.1 lbs. per acre of active ingredient had been applied.

From these preliminary trials, the conclusion was reached that BHC should be applied as a 5% dust, preferably with ground limestone diluent, at not less than 26 lbs. per acre.

The rate of build-up of adult populations

(i) The residual value of DDT and BHC dusts

It was apparent that much more even and effective applications could be given by helicopter than by power duster. Therefore the decision to buy depended only on the economics of the project, *i.e.*, the overheads involved, the cost of operation and the area in which it would be possible for one helicopter to control a severe froghopper outbreak which, in turn, would depend on the rate of build-up of adult populations after treatment.

In routine control, it was found that populations quickly returned to mark 3 after fields had been effectively dusted. It might be argued that each application should have been delayed until the population-time curve had reached a maximum but, in the meantime, the cane would have been blighted and, more important, the eggs which give rise to further broods would have been laid, for female froghoppers pair shortly after emergence and lay their first eggs a few days later.

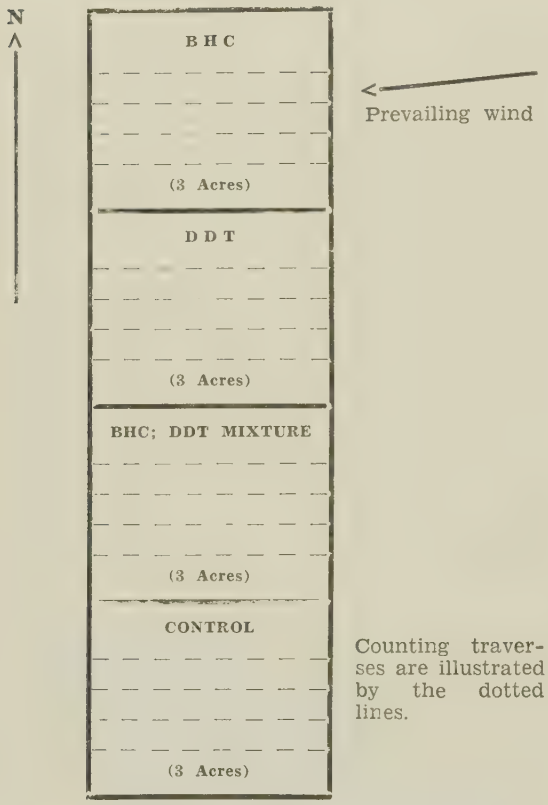
It has been reported (4) that 20 lbs. per acre of 4% DDT dust, applied by the drift dusting technique, caused the adult population to decline progressively for a period of five days after which, for a further period of six days at least, " ..... the population once more commenced to increase slightly, though not to such a degree as to cause economic injury".

It followed that the population build-up might be prevented by using a suitable DDT formulation instead of, or together with, the 5% BHC. One disconcerting fact remained: the failure of morning and the success of afternoon applications of 5% BHC. For should the interpretation of the inefficacy of morning dusting given earlier in this paper prove to be correct, it would be difficult to believe that any insecticide, applied as a dust, could exert a residual effect under typical Trinidad wet season conditions.

Further and conclusive evidence on this point came from experiments in which the effects of 5% DDT, 5% BHC and their 1 : 1 mixture, all applied by helicopter at the rate of 30 lbs.

per acre, were compared with "no treatment". The population was estimated daily by counting the adults present in 300 – 500 stems chosen at random along four closely spaced East – West traverses across the middle of each plot. By combining this counting technique with a suitable plot arrangement, border effects were eliminated and a check was kept on the possible migration of froghoppers into the experimental areas. (See Fig. 1).

Fig. 1.



Field No. F. 108

Insecticides were prepared by diluting both Agrocide 10 (50% BHC) and 50% DDT with ground limestone, the most effective diluent.

Typical results are recorded in Fig. 2. Each of the three formulations on trial, applied to a very slowly emerging brood, caused an excellent initial kill but no residual effect. When, six days after dusting, there was a more rapid rise in the population of the control plot, the treated ones showed greater relative increases. The lack of residual effect of DDT, under the conditions of the experiment, is brought out even more clearly in Fig. 3.

It would appear that in the drift dusting experiment already cited (4), the rate of adult emergence decreased shortly after treatment, so that in the absence of population counts from control plots a natural decline or very slight increase was erroneously interpreted as being due to a residual effect of the insecticide. Alternatively, but less probably, the experiment might have been carried out during a period of drought.

These results support the opinion that the 10% DDT used in the preliminary trials was ineffective because of its unsuitable diluent. More important, they show that hopes of a residual effect arising from applications, as dusts, of the order of 1.5 lbs. per acre of DDT (or BHC for that matter) must be abandoned.

(ii) The effect of increasing the rate of application of BHC dust

In 1947, Potter and Carrington investigated the effect of the dry season application of BHC to the soil on the first brood emergence. They found that 4 cwts. per acre of Agrocide 2 (0.45% gamma isomer or about 3.5% BHC) effectively controlled first brood nymphs and therefore all subsequent broods (10). This work was continued at Reform Estate in 1948; 5 % BHC, applied by hand duster in and around the cane stool at the rate of 2.5 cwts. per acre, was found to give excellent though expensive control. It seemed possible, therefore, that nymphal control might be achieved and the build-up of future adult populations prevented if heavier rates of 5% BHC were applied by helicopter although, after routine dusting (30 lbs. per acre), dead nymphs could not be found even in the most exposed parts of treated fields. Accordingly the relative merits of 30 lbs. and 120 lbs. per acre were assessed.

The field lay-out and counting technique were similar to those described in full in the previous section.

Dusts were applied on the 3rd and on the 12th of August.

Counts, recorded graphically in Fig. 4, show that the first applications were equally effective in causing an immediate adult kill and equally ineffective in failing to prevent the rapid build-up of the population. After treatment with a second application of 120 lbs. 5% BHC per acre, however, the build-up followed the same general pattern as after a second application of 30 lbs. per acre, but at a lower level. The inference is not that a residual effect was achieved by the

THE EFFECTS OF 5% BHC AND 5% DDT DUSTS ON THE ADULT FROGHOPPER (FREDERICK 108)

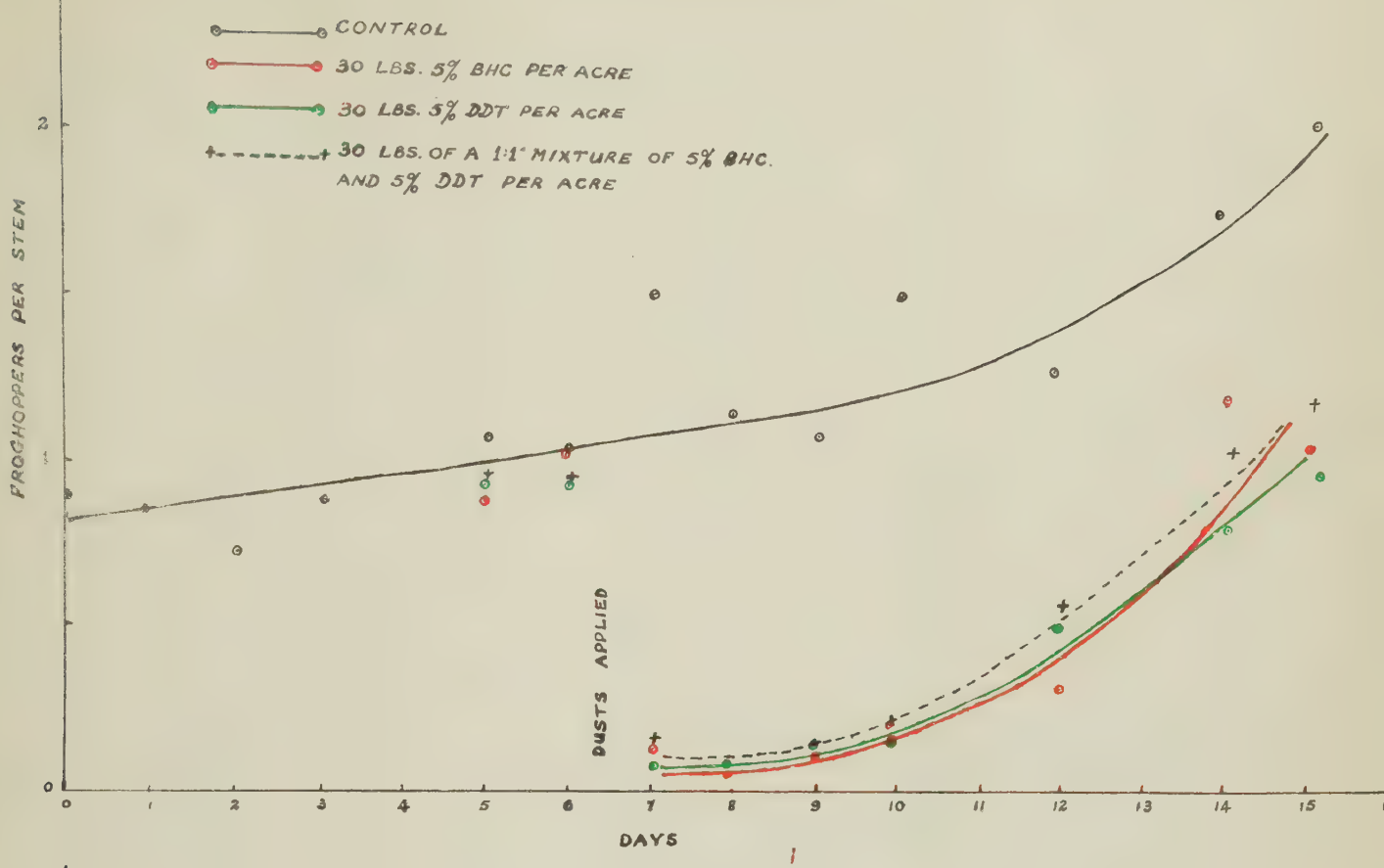


FIGURE 3

THE RESIDUAL EFFECT OF 5% DDT DUST AT 30 LBS PER ACRE ON THE ADULT FROGHOPPER (FREDERICK 129)

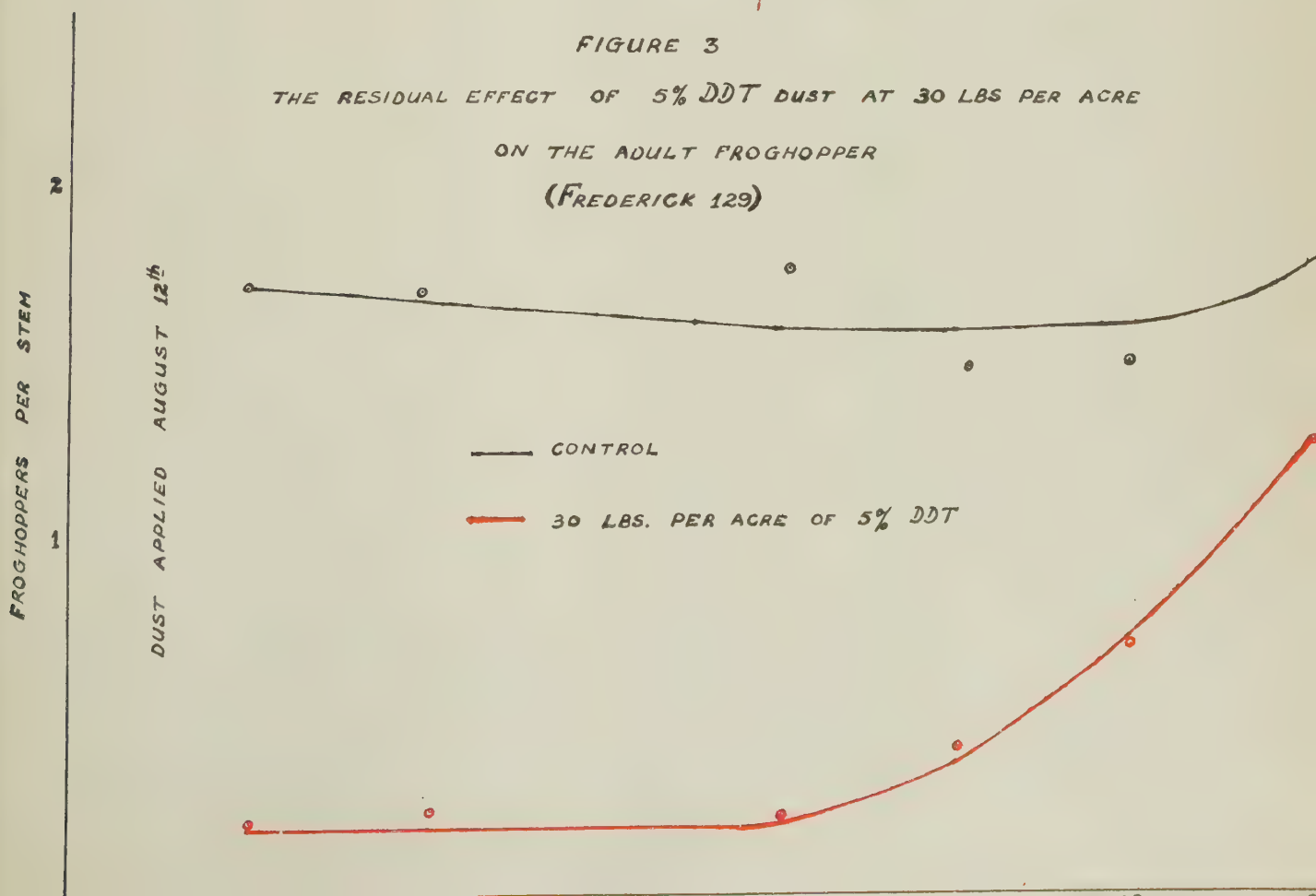
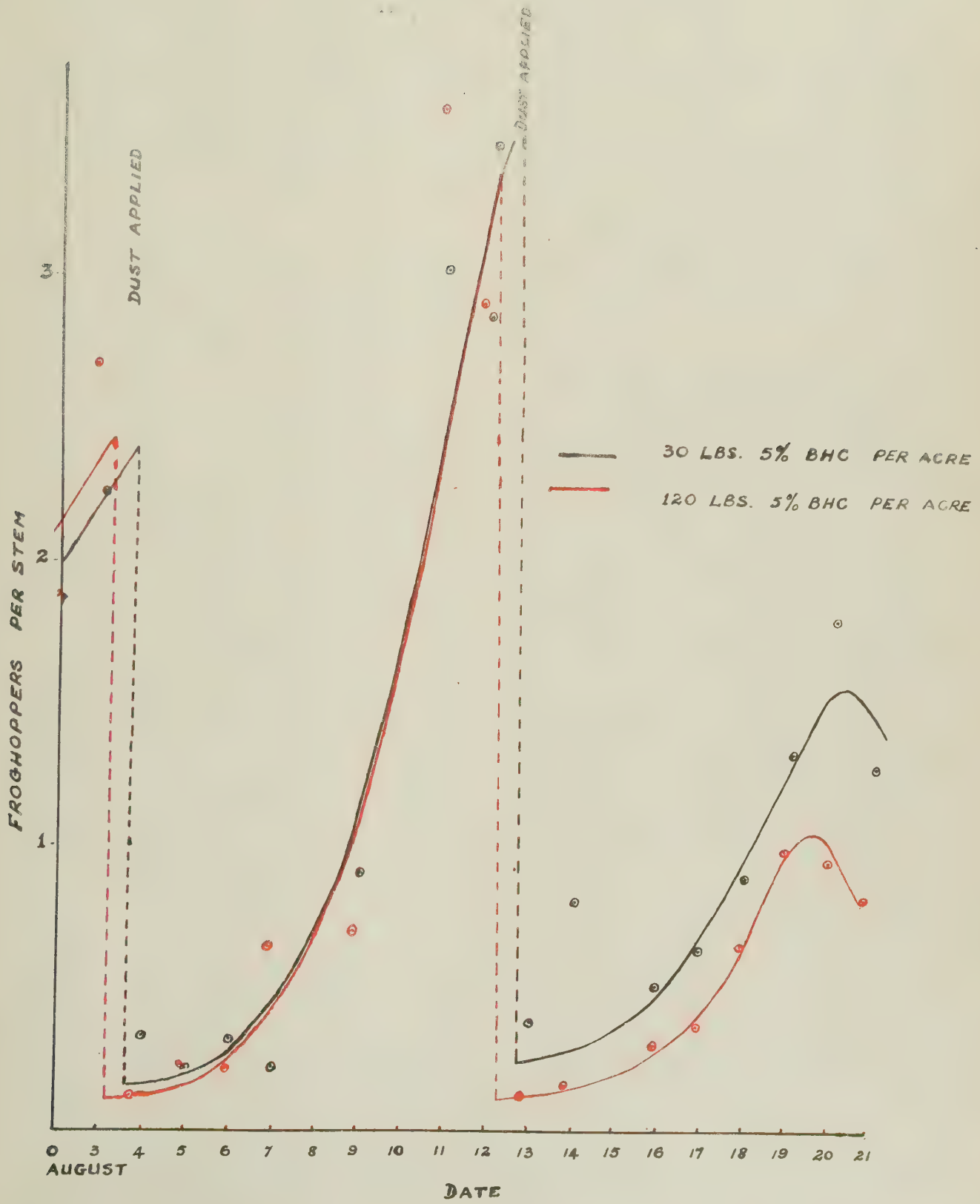


FIGURE 4

FREDERICK 117



heavier application — in which case a differently shaped curve would have been given — but that a definite, though slight, nymphal mortality caused a reduction of 0.3 per stem in the subsequent adult population.

This conclusion is in agreement with the Reform findings that heavy applications can be effective against the nymph ; it also shows that dusts applied against the nymph by helicopter, even at 3 acres per pay load, offer no promise of giving results equal to those claimed for similar applications made from the ground.

(iii) The possible use of oil-based BHC and DDT formulation

The possibility that oil-based insecticidal sprays might give rise to weather-resistant deposits, and therefore to a residual effect, was not fully explored. After much of the preliminary work had been done, the helicopter suffered an accident which prevented its further use.

To sum up : DDT, BHC and their 1 : 1 mixture, all at 5% concentration and applied by helicopter at 30 lbs. per acre, gave excellent initial kills but no residual effect ; two very heavy (120 lbs. per acre) applications of 5% BHC caused a small but negligible nymphal kill with, again, no residual effect ; the value of oil-based insecticidal sprays was not assessed. Therefore the build-up of large adult populations 3 – 6 days after effective dusting, depending on the rate of emergence, could not be prevented.

The acreage covered daily

On the basis of the preliminary trials, morning dusting was abandoned. In the afternoon, attempts to dust before the wind had died down gave patchy results — and often the wind was high at dusk. Therefore it was necessary to fly at night in order that a reasonable acreage might be covered ; this was possible only on moonlit nights and then with the help of flares.

The maximum area dusted by the helicopter in 24 hours was about 200 acres.

The desirability of purchasing a helicopter for froghopper control

Assuming that it would be possible to dust daily, without undue fatigue to the pilot, the pest could be controlled by one machine in a maximum area of 3 x 200 — 6 x 200 acres of cane land.

In the 1948 season the average acreage of Caroni Limited infested with adults, at any given time, was 8,000. In a year of heavy froghopper outbreak it is possible that this area would need to be dusted at intervals of 3 – 6 days. One helicopter would prove hopelessly inadequate to effect control over the whole acreage and much too expensive if its efforts were concentrated on some 1,000 acres.

Nymphal control

It is improbable that any known combination of insecticide and method of application will achieve a residual effect under Trinidad wet season conditions ; to control the pest at reasonable cost by attacking the adult is, therefore, equally improbable. Attacks on the egg and nymph would appear to offer much greater chances of success.

In view of the work on the application of BHC to the soil carried out by Potter and Carrington, the Reform findings and the effects of heavy applications of BHC by helicopter, all of which have been described, the possibility of discovering an economic method of nymphal control was next investigated.

The relative merits of BHC and DDT

An experiment was laid down at Brechin Castle to determine the relative merits of soil applications of DDT and BHC in nymphal control. After the stools had been cleaned the insecticides were applied by hand duster to the soil around the cane roots.

Treatments

1. Control
2. 1 cwt, 5% BHC, with ground limestone diluent, per acre
3. 2 „ „ „ „ „ „ „ „ „
4. 1 cwt. 5% DDT, „ „ „ „ „ „
5. 2 „ „ „ „ „ „ „ „ „

Layout

A randomised block layout with five replicates of each treatment was used. The plot size was 1/112 acre.

Date of Application

On 11th September, 1948, stools were cleaned and dust applied.

Counting Method

Counts of the nymphs in 5 stools chosen at random in each plot were made at weekly intervals.

Results

The results recorded graphically in Fig. 5 show that, shortly after the stools had been cleaned, the average nymphal population of the

control plots fell from 40 to 22 per stool : meanwhile that of the uncleaned part of the field increased to 48 per stool. The disturbance caused by cleaning might have accelerated the rate of emergence of 4th instar nymphs from their last moulting chambers ; however, it is probable that the reduction in numbers was caused chiefly by the many predaceous birds which were observed in the clean experimental area but not in the rest of the field.

During the first fortnight after dusting, the average population of the control plots increased to a maximum of 53 per stool, after which there was a progressive decline in accordance with the usual froghopper brood pattern.

TABLE 3

A comparison of the immediate effects of soil applications of 5% BHC on the Froghopper nymph.

Treatment	10th Sept. 1948						13th Sept. 1948						Difference from the mean of Treatment 2.
	BLOCK						BLOCK						
	1	2	3	4	5	Mean	1	2	3	4	5	Mean	
1. Control	* 38	23	39	54	44	40	26	16	27	23	17	22	+ 20.5 significant at P = 0.01
2. 1 cwt 5% BHC/ac.	47	62	29	46	34	44	0.2	6.4	0.2	0.6	0	1.5	
3. 2 „ „ „ „	44	42	29	53	42	42	1.0	1.2	0.2	0.4	0	0.6	— 0.9 non-signif.
4. 1 „ 5% DDT „	56	72	31	42	29	46	3.8	19	5	2.4	3.6	6.8	+ 5.3 significant at P = 0.01
5. 2 „ „ „ „	32	36	35	41	48	38	9.6	10	8	4.6	1.2	6.7	+ 5.2 significant at P = 0.01

* Each figure in the "block" columns is the average of five stool counts.

Conclusion

BHC, at both rates, caused an excellent initial kill and achieved a marked residual effect ; the population of treated plots remained close to zero for at least 5 weeks — the duration of the experiment — during which period a considerable rise was noted in the control plots (Fig. 5).

DDT was inferior to BHC both with regard to immediate kill (Table 3) and residual value ; the rise in the nymphal population of the control plots was accompanied by small yet definite increases in the DDT-treated plots (Fig. 5). It must be concluded that, under the conditions of the experiment, BHC was much more effective in all respects than DDT.

The success of applications of 1 cwt. 5% BHC per acre which were, nevertheless, concentrated in the area around the stools at much heavier rates, was in striking contrast with the negligible nymphal kill caused by two slightly heavier (120 lbs. per acre) applications of similar material evenly distributed by helicopter and eventually washed into the soil by rain (p. 9).

The effect of varying the rate of application and composition of the BHC dust

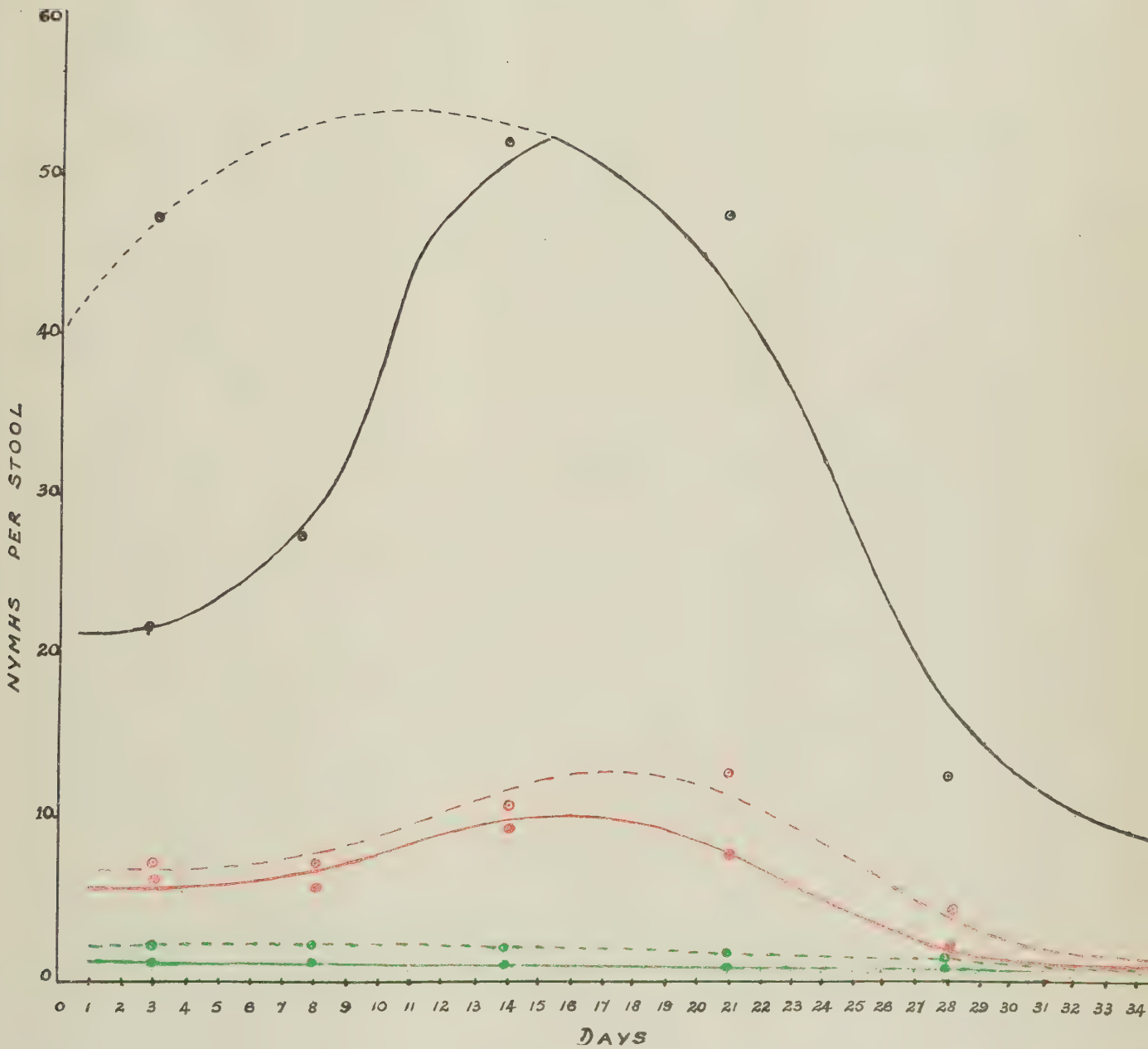
The result of a second experiment confirmed the efficiency of BHC in nymphal control. However, BHC is expensive ; its cost is by far the most important item when the economics of the method are considered. Experiments were laid down to determine the possibility of reducing this cost by using less concentrated formulations for, with the equipment available, it was inadvisable to apply less than 1 cwt. per acre, the lowest rate which would give adequate coverage.

Treatments

1. Control
2. 1 cwt. 1% BHC, with ground limestone diluent, per acre
3. 1½ „ „ „ „ „ „ „ „ „
4. 2 „ „ „ „ „ „ „ „ „
5. 1 „ 3% „ „ „ „ „ „ „
6. 1½ „ „ „ „ „ „ „ „ „
7. 2 „ „ „ „ „ „ „ „ „
8. 1 „ 5% „ „ „ „ „ „ „
9. 1½ „ „ „ „ „ „ „ „ „
10. 2 „ „ „ „ „ „ „ „ „

A COMPARISON OF THE EFFECTS OF DDT AND BHC ON THE FROGHOPPER NYMPH.

BRECHIN CASTLE 36.



CONTROL (UNTRASHED)

CONTROL (TRASHED)

1 CWT. 5% DDT PER ACRE

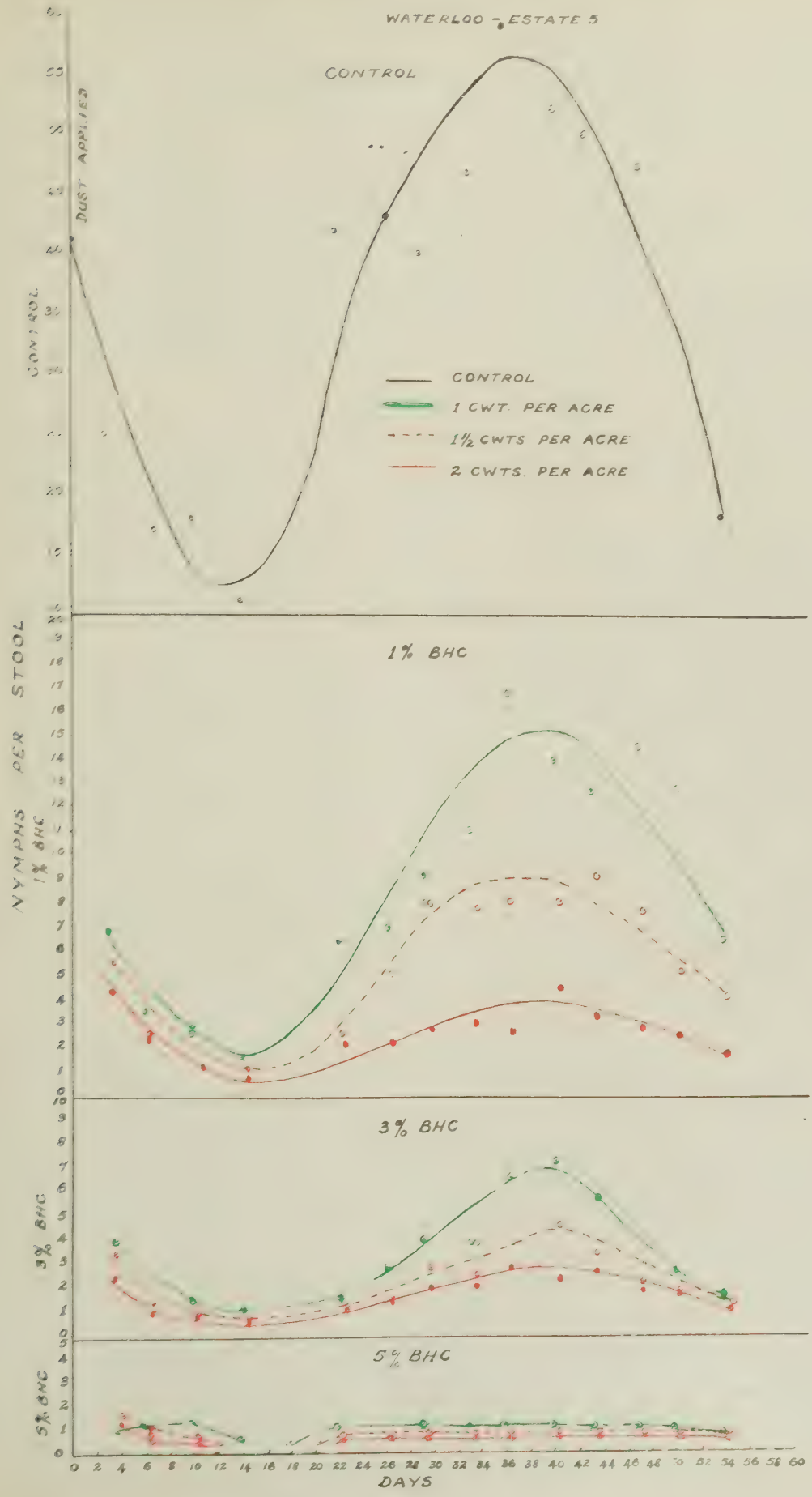
2 CWTS. 5% DDT PER ACRE

1 CWT. 5% BHC PER ACRE

2 CWTS. 5% BHC PER ACRE

FIGURE 8

THE EFFECT OF BHC ON THE FROGHOPPER NYMPH



Layout

A randomised block layout with 5 replicates of each treatment was used. The plot size was 1/112 acre.

Counting Method

The experimental fields, Waterloo Section Estate 5 and 95, had been planted "continuously", *i.e.*, with whole stalks instead of 3-eyed setts; for counting purposes, 3 ft. of the resultant continuous cane rows were regarded as the equivalent of 1 stool. Counts of the nymphs in 5 stools, chosen at random in each plot, were made at intervals of 3 – 4 days.

Results

The results recorded graphically in Fig. 6 for Waterloo Section Estate 5, show that, at the time of application, the nymphal population was decreasing rapidly. Fourteen days later a sharp rise in the control plots indicated the hatching of the next brood; the nymphal population — time curve reached a maximum of 60 per stool 5 weeks after the dust had been applied and then followed the usual brood pattern in a swift decline.

Counts made on the day after treatment showed that 1%, 3% and 5% BHC had caused the average nymphal population to fall to 5, 3 and 1 per stool respectively, and that, in general, only slightly better kills had been given by increasing the rate of application of a dust of fixed composition from 1 cwt. to 2 cwts. per acre.

Later, when nymphs of the succeeding brood appeared in the control plots, corresponding increases were noted in the population of those which had received dressings of 1% and 3% BHC. Eventually, maxima of 15, 9 and 4 nymphs per stool were reached after treatment with 1% BHC at 1, 1½ and 2 cwts. per acre respectively; the comparable figures for 3% BHC were 7, 4 and 2.5 per stool. Meanwhile the population of those treated with 5% BHC, at all rates, remained close to zero.

It must be concluded that, under the conditions of the experiment, 5% BHC was much more effective than either 1% or 3% BHC, giving a better immediate kill and preventing the build up of the nymphal population after treatment.

The Residual Value of BHC Dust

The data recorded in Brechin Castle 36 (Figure 5) show that, 6 to 15 days after application, nymphs emerged in the control and DDT-treated plots; most if not all of the eggs which hatched during this period must have been laid before the plots were dusted. In laboratory incubation studies it has been found that BHC does not prevent the normal development of the froghopper egg. Therefore, as the nymphal population of BHC-treated plots remained close to zero, the inference must be drawn that this insecticide retained its lethal qualities for 15 days at least.

In Waterloo Section Estate 5, the build up of the nymphal population of the control, 1% and 3% BHC-treated plots began 12 days after application. It might be urged that 12 days is close to the minimum incubation period of the froghopper egg, therefore the excellent nymphal kill given by 5% BHC eliminated the adult progenitors of the succeeding brood. However, reference to Figure 5 shows that the dusts were applied to a declining nymphal population, *i.e.*, adults were already present in the experimental field in large numbers. Further, although some eggs will hatch in 14 days, others, in increasing proportion towards the end of the season — at which time this experiment was carried out — require much longer periods of incubation (11). For example, in experiments with ovicides under field conditions in 1948, nymphs first appeared in "control" cages five weeks after the death of the last adult. The implication is that many eggs hatched in those plots treated with 5% BHC during the period 12 to 36 days after application and that the build up of a nymphal population was prevented only by the residual effect of the insecticide.

Suggestions that the froghopper might be controlled in the nymphal stage are usually greeted with scepticism; reference is made to "Cyanogas" (calcium cyanide) which once was used for this purpose on most estates in Trinidad. Pickles' views on its value are worthy of note: "The material (Cyanogas) must come into actual contact with the spittle masses surrounding the insect and its utility will be seriously reduced if a large population of the nymphs is situated beneath the soil ..... Cyanogas is not effective if used much before or much after the peak of the nymphal emergence and, if the nymphal population is extremely large, and its emergence very protracted, Cyanogas dusting is insufficient to prevent serious blight" (3, p. 118). Elsewhere, it has been reported that, when applied in this manner, the period of its lethal activity is very short — probably only 4 – 6 hours (12). There can be little doubt, then, that Cyanogas was effective in giving an immediate nymphal kill and was discarded primarily because of its negligible residual value, secondarily, because of the labour requirements of a method which involved repeated applications to infested fields.

Recently attention has been drawn to the remarkable persistence of DDT and BHC in soil (13). In an experiment carried out at Wye, it was found that 95% DDT and 80 – 94% BHC

were still present 18 months after application (14). These findings are in agreement with the evidence given in Figs. 5 and 6 that 1 cwt. 5% BHC per acre, applied to the surface of the soil, still proved lethal when nymphs emerged several weeks later. It must be inferred that such applications would control the first brood even if emergence was protracted, and therefore all subsequent broods; further dusting would be unnecessary. Thus, BHC possesses those qualities for lack of which Cyanogas was unsuccessful in nymphal control.

In view of past disappointments one hesitates to claim that an economic solution to the froghopper problem has been found. However, there appears to be no reason why the pest cannot be controlled at a cost of roughly $7.00 per acre by applying 1 cwt. 5% BHC per acre by hand duster to the cane stool.

For satisfactory control by this method the insecticide must be applied within 5 weeks of the first appearance of spittle (nymphs). Although further treatment should be unnecessary, the need to "time" the applications will make demands on the labour force which, if excessive — unlikely in a country where hand weeding is still standard practice — might cause the operation to be mechanised.

The Use of Ovicides

The time limits would be much wider and this problem would not arise if a method involving the use of an ovicide could be elaborated. Such a chemical, applied after harvest, would kill the long-cycle eggs and thereby eliminate the first and therefore all subsequent broods.

Although Cyanogas was the most effective of several ovicides tested in the laboratory under the auspices of the Froghopper Investigation Committee, its promise was not fulfilled in field tests (15). There appears to be no record in the literature of the effects of the more recently developed ovicides on froghopper eggs.

Such an investigation is being carried out by this department. Preliminary trials with DNOC (dinitro-o-cresol) have given most promising results; during the 1949 season it is proposed to test the ovicidal properties of a wide range of chemicals.

Acknowledgments

Reference has already been made to some of the numerous people who helped these investigations in many ways; special mention should be made of Messrs. K. Potter and J. Carrington of Geddes Grant Ltd., and Mr. J. Mayers of Reform Estate.

Mr. Capper, the pilot, was most helpful in carrying out the helicopter trials. Mr. L. Harvey of the Shell Experimental Station, Sittingbourne, suggested the use of DNOC and cooperated in the preliminary experiments with ovicides. His help in this and other directions was most valuable.

The main burden of carrying out the experiments described in this paper, however, fell upon the staff of the Research Department of Caroni Limited. Mr. P. de Verteuil was in immediate charge of the routine helicopter operations and of the froghopper experiments carried out in 1948. I am much indebted to him and to the other members of the department for their loyal and hard work.

Finally, acknowledgment is due to Messrs. Caroni Limited for permission to publish this paper.

References

1. Hart, J. H., Report on Sugar-cane Blight, Agric. Record Trinidad, *II*, pp. 126-128 (1890), quoted by Pickles, A., reference 6, p. 116.
2. Williams, C. B., Report on the Froghopper — Blight of Sugar-cane in Trinidad; Memoirs of Dept. of Agriculture, Trinidad, No. 1 (1921).
3. Pickles, A., *Tropical Agriculture,* Vol. *XIX* pp. 116-123 (1942).
4. Pickles, A., *Tropical Agriculture,* Vol. *XXIII* pp. 9-11 (1946).
5. Pickles, A., Proceedings of Agricultural Society of Trinidad and Tobago, Vol. *XLVI* pp. 149-154 (1946).
6. Pickles, A., *Tropical Agriculture,* Vol. *XIV* p. 5 (1937).
7. Withycombe, C. L., *Annals of Applied Biology,* Vol. *XIII* pp. 64-108 (1926).
8. Colonial Insecticides Committee, First Annual Report para. 43 (b) (1947-8).
9. International Sugar Journal, Vol. *L* p. 255, (1948).
10. Potter, T. E. K., and Carrington, A. J., Report on the Effect of Soil Application of Gammexane Formulations on Sugar-cane Froghopper Incidence (1947).
11. Proceedings Froghopper Investigation Committee, Trinidad, Vol. 2 p. 62 (1928).
12. Hardy, F., Proceedings Froghopper Investigation Committee, Trinidad, Vol. 1 p. 95 (1926).
13. Carne, P. B., *Nature* 162, p. 743 (1948).
14. Smith, M. S., *Nature* 161, p. 246 (1948).
15. Rodrigues, G., Proceedings Froghopper Investigation Committee, Trinidad, Vol. 1 pp. 348-351 (1927).

Received for publication, March, 1949.

NOTES ON THE GRAZING LANDS OF BRITISH GUIANA

BY

G. C. Stevenson,

(Chief Research Officer, Department of Agriculture, British Guiana.)

Introductory

The stock-rearing industry of British Guiana has been developed in two separate and very distinct environments: the low-lying coastal plain, and the hinterland savannahs of the Rupununi district. A few animals are raised in local forest clearings along the banks of the navigable rivers, but such pastures represent only a small fraction of the very considerable grazing lands of the Colony. In the intermediate savannahs, comprising an area of some 2,000 square miles, all attempts to raise cattle have been unsuccessful until quite recently when investigations there have shown that deficiency in minerals explains the previous lack of success, and indicate that there is considerable promise of establishing a ranching industry by applying the experimental results obtained.

The coastal pastures and the Rupununi savannahs differ radically in almost every respect — climate, soil type, indigenous flora, and the methods required for successful stock-raising. They represent an interesting contrast in the problems of pasture methods of approach in formulating research work for improvement of grazing conditions.

In the following paragraphs, brief descriptions of the pasture lands are given, together with notes on the methods of livestock management in use so far as they influence pasturage conditions, on experimental work in progress to improve grazing quality, and on future research work envisaged. A final section records briefly the investigational work done in the intermediate savannah district, and indicates the possibility of developing a stock-raising industry there.

The coastal pastures

The soils of the coastland plain of British Guiana are mainly sea-borne clays, situated for the most part at or slightly below sea level. Some distance inland, the clay has superimposed upon it a layer of " pegasse " of varying depth. This material is of the nature of peat, and is formed by the decay of vegetation under swampy conditions. The average annual rainfall is about 90 inches.

Most of the coastal belt has been used at some period for sugar cane cultivation, for which purpose it was protected from inundation by a sea-wall, surrounded by dams to keep out water from the inland swamps, and intersected by canals for drainage and irrigation. In the early days of cane cultivation, before the principles of fertility conservation were appreciated, soil exhaustion took place after several crops had been taken. Cane cultivations were shifted progressively inland and are now often several miles from the coast, while the front lands have been abandoned and allowed to revert to grassland or are used for rice cultivation. So far as the grasslands are concerned, their type and value for grazing varies according to the extent to which drainage has been efficiently maintained. The drier pastures support a flora consisting mainly of the grasses of *Capriola dactylon, Sporobolus indicus, Paspalum conjugatum* and *Panicum laxum,* with *Paspalum distichum* common in drainage trenches and moist hollows. The sedges *Fimbristylis monostachya* and *Cyperus* spp occur commonly in association with the grasses. Carpet grass *(Axonopus compressus)* is found spasmodically, particularly under shade and where the grass is closely cut or grazed heavily. Two creeping legumes, *Alysicarpus vaginalis* and *Desmodium triflorum* are sporadic constituents of the sward. The proportion of the constituents varies according to the degree of moisture present and the heaviness of grazing or cutting practised. Where heavily grazed and overstocked, as is often the case, the pasturage consists on the dry ground mainly of *Capriola dactylon* with a little *Axonopus compressus,* and in the hollows *Paspalum distichum.*

The wet pastures which occur over large areas of the coastland have developed on land which is poorly drained. They alternate between periods of almost complete submergence and times when they are merely waterlogged, though in prolonged rainless spells they may become completely dry. It is a common sight during the rains to see cattle in such pastures belly-deep in water, unconcernedly grazing the semi-aquatic grasses and sedges. *Paspalum distichum* and *Panicum geminatum* often dominate the grass flora, with *Sporobolus virginicus* and a number of sedges such as *Cyperus articulatus* commonly occurring. *Capriola dactylon* appears only on the drier patches and dams.

In the pegasse pastures further inland where there is considerable stock-rearing, the typical grass constituents are *Paspalum virgatum,* which is only grazed when young and tender, *Hymenachne amplexicaulis, Homolocenchrus hexandrus* and *Echinochloa colonum,* with *Capriola dactylon* in the drier parts. Under conditions of

overstocking, *Hymenachne amplexicaulis*, which thrives under wet conditions, frequently is the only grass survivor, and occurs in pure colonies intermixed with the sedge *Cyperus articulatus*. Where grazing is controlled, *Homolocenchrus hexandrus*, a species grazed very readily by cattle, is often dominant, occurring with *Panicum laxum* in addition to the above-mentioned species. Generally speaking, on these pegasse pastures the proportion of grasses to sedges increases with improved drainage, and the more valuable grazing grasses are in greater proportion where the land is fenced and not overstocked.

Although some of the pasture land in the coastal belt is well-drained and properly managed, it is nevertheless true that the vast majority is little more than semi-abandoned and waterlogged mud-flat, generally over-stocked and badly managed, where ill-conditioned animals compete for the meagre vegetation which the swampy land can produce, and destroy as much grass by trampling in the mud as they consume.

The improvement in pasture conditions in the coastal area is bound up primarily with the important features of drainage and control of the stock population by improved fencing and rotational grazing. Both these measures require considerable capital expenditure, but little improvement in grazing conditions can be forseen without such expenditure in the first instance. The majority of stock-owners on the coastal plain do not own or rent grazing land. In such cases stock is either stall fed, or kept on the agistment system, by which animals are allowed to graze in large pasture areas (owned either by sugar estates or by private individuals) in return for payment of a small monthly charge per animal. It is hoped that improvement of grazing in such agistment areas will be possible when stock-owners have been persuaded of the principle that one well-bred and well-nourished animal is more profitable than three half-starved scrub beasts. An increase in agistment fees in the first case will be justified if owners of the lands are to incur expenditure in drainage works and improved fencing. Improvement of the animals themselves should result in time from the policy of castration of scrub bulls and provision of better-bred sires.

Irrespective of the methods of pasture management, analyses of herbage have shown that its feeding value is generally somewhat low on the coastland, particularly in protein and mineral content.

Experimental work is in progress with various pasture grasses and legumes. Plots of the following have been established and will be used to obtain information on yielding capacity on the coastal clay soils :— *Axonopus compressus* (2 strains), *Andropogon annulatus, Chloris gayana, Stenotaphrum secundatum, Paspalum notatum*, and the legumes *Indigofera endecaphylla, Alysicarpus vaginalis, Desmodium triflorum, Pueraria phaseoloides, Teramanus labialis* and *Medicago sativa*. The legumes are being grown pure and also in association with various of the pasture grasses with the object of developing a permanent grass-legume mixture which will stand controlled grazing.

The addition of suitable perennial legumes to the natural coastland pastures should serve to increase the protein content of the herbage and improve its feeding value. Improvement of the mineral content would be possible by means of artificial fertilisers, but whether such a procedure would be economic must await the results of the experimental work which is envisaged.

The Rupununi savannahs

The Rupununi savannahs are situated in the southern part of British Guiana, and cover an area of more than three million acres. They are divided into two sections by the Kanuku Range of mountains, and represent an extension of the vast savannahs of Venezuela and Brazil. The altitude is some 200-300 feet above sea-level, and the average annual rainfall about 50 inches. The northern savannahs, some 2,000 square miles in area, consist of rolling grasslands with numerous large swamps which are under water in the rainy season. Many creeks and streams intersect the grasslands to flow into the tributaries of the Essequibo and Takutu Rivers. The southern savannahs, covering an area of some 2,500 square miles, are more mountainous in character : they are continued across the Rio Brancho into the State of Amazonas in Brazil.

The soils of the Rupununi savannahs are somewhat variable, but consist mainly of acidic sands with acidic loams in the foothills of the mountains. They are generally low in organic matter, lime, and phosphate. From the air, evidence of considerable soil erosion can be seen throughout the district.

The natural savannah grasses are fibrous, and xerophytic in character. *Trachypogon plumosus* is dominant over large areas, and other common species are *Axonopus aureus, Andropogon angustatus, Leptocoryphium lanatum*, and *Paspalum carinatum*. These savannah grasses are predominantly tufted in habit, and do not generally form a turf. In the dry season they become tough and wiry, with little nutritious herbage suitable for grazing, and it has been the habit for many years to burn off the savannahs in order to encourage a fresh spring of growth. Where the buring has been practised for long periods, and the valuable organic matter of the vegetation thereby destroyed, conditions

Rupununi Savannah.

Rupununi Savannah Land showing soil erosion.

Rupununi Savannah, showing *Trachypogro Plumosus* association.

Animals grazing on flooded coastal pasture.

which lead to soil erosion are being progressively developed. The sandy nature of the soil, and the absence of a complete vegetation cover, serve to hasten this degenerative process and to render it more serious in its effects.

Analyses of typical savannah grasses prove them to be low in silica-free ash, lime, phosphate and potash, and consequently of rather poor nutritive value to stock. With the exception of a few paddocks which are maintained alongside the larger ranches, there is virtually no attempt at pasture management. Cattle are maintained on the open range system, and as the savannahs are much understocked and the animals tend to concentrate where the grazing is best near the creeks and foothills, the result is that large areas of the savannah are left almost untouched.

The cattle population of the Rupununi numbers more than 50,000 head, but the savannahs are so vast that this total only represents one animal per 75 acres or so. Animals on the hoof, however, removed from the ranches and sent to the coast for slaughter, have been estimated to carry away some 45 to 50 tons of calcium and phosphorus every year. Such a continuous drain over a long period of years must be of serious consequence where the soil and vegetation are known to be low in these essential elements, and where there is no replacements other than by the slow regenerative processes in the soil.

The absence of any serious attempts to improve the savannah grazing, or to introduce a more intensive system of stock-raising, must be largely ascribed to the open-range ranching system, and to the inaccessibility of the Rupununi region. It can be reached only by river, which may take four or five weeks, by the 200-mile-long cattle trail through the forest from the Berbice River, which necessitates riding with pack animals to carry goods, or by air. By any of these means, the cost of introducing stores, fertilisers and other supplies is an important consideration. With the present cost of fertilisers, and with freight charges in addition, it is unlikely that any large-scale programme of manuring of the savannah grazing could prove an economic proposition. For the present, improvement is likely to take place by the extension of superior grasses — *Melinis minutiflora* has been shown to give good results under savannah conditions — and by the construction of more fenced paddocks for controlled grazing near the ranch headquarters. In addition, the results from research work envisaged at Ebini Station on the amelioration of pasture conditions by use of the animals themselves, which is referred to in the following section, should be generally applicable to the Rupununi conditions.

The Intermediate savannahs

The Intermediate savannahs are situated in the Berbice district, some 80 miles from the town of New Amsterdam and within easy reach of the Berbice River, which is navigable by cattle boats. They comprise an area of some 2,000 square miles of undulating savannah country, with small bush islands. The altitude is about 80 feet above sea level, and the rainfall some 80 inches per year. The soils are mainly acid sands, deficient in lime, phosphate, potash and organic matter. The natural vegetation is a coarse and fibrous grass-sedge association, which is only palatable to stock when freshly burnt. The predominant grasses are similar to those occurring in the Rupununi: *Trachypogon plumosus* is the most common, and *Axonopus aureus* and *A. stragulus* are frequent. Analyses show that these grasses are even lower in nutritive value than those of the Rupununi.

Attempts have been made from time to time to raise cattle on the Intermediate savannahs, but until recently all were unsuccessful, as animals lost condition rapidly, and failed to breed. One ranch has been maintained for several years as a resting place for cattle arriving by the trail from the Rupununi, before shipment to the coast. Cattle cannot be kept there for more than a few months, however, without falling off seriously in condition.

In view of the large area of available grazing land, and its relative accessibility, a Government Livestock Station was opened at Ebini in 1941 with the object of investigating the practicability of cattle raising in this district. The first main objective of the Station has already been attained: it has been shown that previous lack of success was due to mineral deficiency of the pasturage, and at present animals are bred and raised on the savannah and brought to a suitable condition for market. They have access at all times to a mineral supplement which maintains them in good condition.

Simultaneously with the work on cattle at Ebini, experiments with introduced grasses and legumes, and with methods of pasture improvement, have been in progress. Wynne grass *(Melinis minutiflora)* has been shown to be well suited to the conditions, and now occupies some 40 acres of fenced pasture. Following a light dressing of phosphate and a leguminous cover crop, this grass forms a good sward which is readily grazed by stock. Carpet grass *(Axonopus compressus)* and Bahama grass *(Capriola dactylon)* succeed where heavily grazed and dunged by stock. Of the introduced legumes, *Indigofera endecaphylla* and *Alysicarpus vaginalis* are the most promising.

A comprehensive programme of future investigation at Ebini has been formulated. For

pasture improvement, the testing of additional introduced grasses and legumes will be continued, and fundamental research on the methods and economics of pasture management will be undertaken. In the latter respect, it seems unlikely that for the immediate future the use of considerable quantities of artificial fertilisers for pasture extension would prove an economic proposition. Consequently, while fertiliser trials will be carried out in experimental plots, research will be mainly aimed towards alternative methods of improving the grazing. Most important of such methods are those making use of the biotic factor, in which the animals themselves are used to bring about ecological changes. Preliminary indications are that with heavy grazing and dunging under controlled conditions, a considerable improvement in pasturage is possible. The results from such fundamental research should be of great significance. They might make possible the settlement and utilisation of the Intermediate savannahs, and would be also applicable to the conditions in the Rupununi area.

Literature

In the preparation of the above notes, reference was made to several unpublished reports in the files of the Department of Agriculture, and to the following publications :—

(i) Miller, Wm. C. Survey of Animal Husbandry, Feeding Management & Veterinary Services in the West Indies — *British Guiana Report. Development and Welfare in the West Indies, Bulletin* No. 19A, 1946.

(ii) Follett-Smith, R. R. An Agricultural Survey of the Waranama Savannah, Berbice River. *Agric. Journ. of British Guiana,* III, 1930.

(iii) Follett-Smith, R. R. and Frampton, A de K. Report on Agricultural Conditions in the Rupununi District and Pakaraima Mountains. *Agric. Jour. of British Guiana,* VI, 1935.

Received for publication May, 1948.

REVIEW

GROWTH SUBSTANCES AND THEIR PRACTICAL IMPORTANCE IN HORTICULTURE

BY

H. L. Pearse

(Technical Communication No. 20 of the Commonwealth Bureau of Horticulture and Plantation Crops. 1948. pp. 233 bibl. 1471, 12/6).

The present review has brought up to date (1948) Dr. Pearse's previous work on the utilization of plant growth substances in horticultural technique. That there has been a considerable demand for an authoritative review of recent achievements in the subject is shown by the number of reviews and publications which have recently appeared. None of these has, however, covered the world-wide field of research and practice in the applications of plant growth substances in the manner which Dr. Pearse's latest publication has done.

Reviews, in general, may be classified into two types ; first those which constitute a comprehensive compilation and summary of published work presented in an orderly and logical arrangement under appropriate headings, and secondly those which are mainly a critical analysis of published results based on an evaluation of the relevant experimental data, experimental technique and theoretical considerations based on conclusions from related fundamental research.

Although Dr. Pearse is eminently qualified to produce a critical review the present work falls largely in the first category ; nevertheless, summaries and recommendations with respect to aspects which are no longer controversial are included. Providing that the literature is adequately covered and not unduly selective there are advantages in the first type of review. It leaves the reader free to arrive at his or her own evaluation of the status of any particular aspect of the subject : for the practical horticulturist, it provides the facts and does not enter into any controversial discussion. For the trained research worker however, a critical review is useful in focussing attention on discordant data and emphasises the gaps in our knowledge and the directions in which further work is most urgently required.

The extensive literature covered in Dr. Pearse's review and the limitation of size makes it inevitable that some aspects receive a more thorough and well-balanced treatment than others. Indeed it is probable that a considerable improvement in the value of the publication would have been achieved by limiting the present review to those aspects of growth promoting substances which are concerned in growth processes in the positive sense and to deal separately with their role in the destruction of plant life, *i.e.*, in their use as herbicides. The

latter subject requires a publication to itself if equal justice is to be done to the extensive recent researches on the subject.

The section on the use of growth substances in vegetative propagation and in the treatment of seeds, seedlings and growing plants is particularly well treated and Dr. Pearse does well to emphasize that these treatments should be regarded as a supplement, rather than as in any way a replacement, of the methods normally used by the propagator. What is probably a typographical error, but an important error, occurs on p. 18 para. 5. The concentrated solutions used by Hitchcock and Zimmerman were, of course, 1–20 mgrm. *per millilitre* and not 1–20 mgrm. per litre as stated in the text.

It would probably have resulted in greater clarity for the uninformed reader if the change with time in the significance of the term "rhizocaline" had been brought out in the text. Thus on p. 11 Bouillenne and Went's first use of the term to denote "the special root forming substance", at that time unknown, is defined. On p. 13 following the recognition of the root forming activity of β indolyl acetic acid it is stated "The special term 'rhizocaline' for the root-growing hormone was therefore no longer necessary". On p. 31 it is further stated, "It was concluded that the indolyl acetic acid did not increase the total potential number of roots but speeded up the process of formation, by mobilizing the internal factor (rhizocaline) and could only be effective when this factor was present in the tissues". Some explanation of the birth, death and resurrection of the term "rhizocaline" would appear necessary. In its present meaning "rhizocaline" denotes a substance postulated by Went (other than known natural or synthetic growth promoting substances) as being essential to root formation. It is postulated that the substance is manufactured in the leaves and from thence transported to the region of root induction. Similar substances — caulocaline and phyllocaline were thought by Went to be concerned in stem and leaf initiation. Van Overbeek and his co-workers have claimed that in Hibiscus, the hypothetical function of "rhizocaline" may be replaced by carbohydrates and nitrogenous compounds, as is fully explained by Dr. Pearse. The fact that so many varieties and species of plants fail to root unless they are in a certain physiological condition — in spite of application of root promoting substances and adequate nutrients of all types affords considerable evidence of the existence of a missing factor or factors other than a nutritional condition and for which, for the present, the term "rhizocaline" is a convenient one to use.

In the reviewer's opinion insufficient emphasis is given to the interesting recent work on substances having an effect countering that of the growth promoting substances, *e.g.*, tri-iodobenzoic acid which at low concentrations appears to increase the effect of auxin while at higher concentrations it appears to compete with auxin, and can nullify the effect of the latter. Current views of the mechanism of action of dormancy-breaking compounds such as ethylene chlorhydrin in destroying or nullifying the effect of growth promoting substances could with advantage have been discussed in greater detail.

The tabulated list of results obtained with cuttings of various species will be found particularly useful both by the practical horticulturist and by the research worker on growth substances. It is surprising to find such an important tropical crop as cacao missing from the list. Cuttings normally used for the propagation of cacao respond well to treatment with growth promoting substances.

The use of synthetic growth substances as weed killers is dealt with in a rather sketchy manner and there has been a serious inadequacy in reviewing the literature on this subject. To take but one example — a substantial amount of work on the control of weeds in sugar-cane has been carried out in the U.S.A., the West Indies, Australia, South Africa, Mauritius and elsewhere, but the only publication mentioned is that of Overbeek, Gregory and Velez (1946). These workers claimed to have eradicated *Cyperus rotundus* L. with a single application of 0.3% 2, 4-dichlorophenoxy acetic acid and, in the absence of other references, the reader would be justified in assuming that this single selected reference was typical. In fact, elsewhere it has been proved impossible to *eradicate* as contrasted to *suppressing Cyperus rotundus* even with three or more applications of much higher concentrations of 2–4 dichlorophenoxy acetic acid. Provided that it is granted that the section on weed control does not claim to be a full up-to-date account of the status of this subject, it serves a useful introduction to the subject. It would be difficult, however, to deal with such an extensive subject within the scope of the present publication and any limitations in this section must not be allowed to detract unduly from what is on the whole an excellent and most valuable review of the uses of plant growth substances in horticulture published at the modest price of 12/6 and which compared to many recent text books on the subject is extremely good value for the money.

H. E.

A NOTE ON NITRATE ACCUMULATION IN A UGANDA SOIL

BY

G. ap Griffith and H. L. Manning
(Department of Agriculture, Uganda).

Previous work (1) carried out in Uganda had shown variations in nitrate nitrogen of a soil under coffee with different ground treatments. As the quantities of nitrate then found were of somewhat higher order than those commonly reported in the literature, it was decided to re-open the enquiry. The present paper reports the preliminary phase of a new series of observations made at the Kawanda Agricultural Research Station, Uganda.

Description of Site

The site chosen had been under cultivation (without grazing) for some years and under cotton the previous season, and has a western aspect with a 2° slope. The soil is a medium-textured loam, pH 6.3, of medium nutrient content (about 8 mgm. equiv. per cent) and a nitrogen content of 0.138 per cent, overlying a freely-drained medium-textured red-brown subsoil of considerable depth. The average yearly rainfall is 43″. Details of the rainfall for the 12 months of these observations are shown in the accompanying diagram.

The plot was mulched with *Pennisetum purpureum,* 6″ deep, in five alternate strips, three yards wide; five alternate strips of equal width were left bare. Both mulched and bare strips were kept clear of weeds by hand weeding.

Description of observations made and method of sampling

Samples for nitrate determination were taken weekly with a screw auger at 6″ and 12″ depths. Five cores from each strip were combined to give two bulk samples from the mulched and two from the bare strips from which aliquots were taken for nitrate determination, carried out by the distillation method described by Piper, *Soil and Plant Analyses,* 1942, p. 206, and for moisture determination. A continuous record was kept of soil temperature at 2″ and 8″ on the bare strips and for a period of three months at 2″ under the mulch.

Statement of results

The accompanying diagram shows a histogram for rainfall and curves for nitrate and moisture. To simplify discussion for the purpose of this paper, these are presented as weekly means of moving averages of three weeks.

(a) Bare soil

It is shown that, on the bare soil, for every increase in rainfall there is an accompanying increase in nitrate with the exception of the slight fall in nitrate corresponding with the period ending May 31st.

The onset of the rains in March was accompanied by an immediate rise in nitrate to over 200 p.p.m., a rise which was continued through the rainy period to a maximum value of nearly 500 p.p.m. (This single value does not appear in the diagram). The rise was somewhat irregular, and it is to be particularly noted that a fall occurred in the period ending May 31st.

It is possible that this irregularity is due to a super-position of a leaching effect upon increased nitrate production. It will be noted that the soil moisture content at the time of the fall in nitrate content was over 22 per cent., this being the only occasion throughout the year when the soil moisture approached this figure. Hardy (2) draws the inference from his observations in the West Indies and elsewhere that nitrate accumulation in a soil will occur only when the monthly rainfall is less than 2.4 ins. and is probably lost by leaching when the rainfall exceeds 4.0 ins. in a month. It is probable that this figure would vary under different conditions of soil and of effective precipitation.

The present results indicate that, under Uganda conditions, nitrate accumulation does not take place until the monthly rainfall attains a minimum effective precipitation. At this stage we have not attempted to assess what this minimum effective precipitation may be.

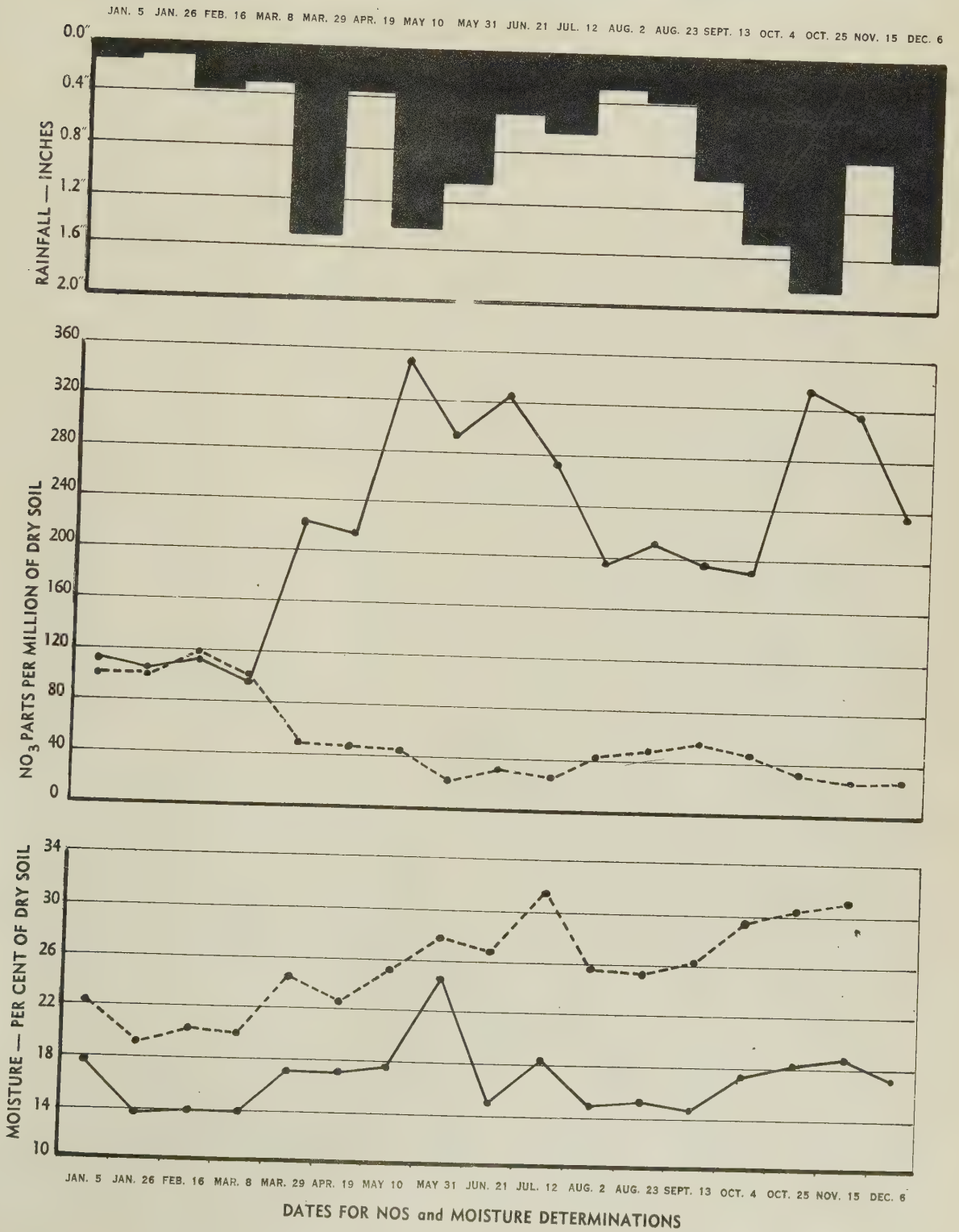
The results also suggest that, when the effective precipitation exceeds a certain figure, the leaching effect, which is then superimposed upon the nitrate formation, may be sufficient to obscure the latter.

(b) Mulched soil

The mulch was applied during a dry period when the nitrate content of the soil already stood at about 90 parts per million NO_3. The application of mulch had no immediate measurable effect upon the nitrate content, whilst the moisture content on the other hand responded immediately and varied between 18 and 22 per cent. as compared with between 14 and 16 per cent. on the bare soil.

With the onset of the March rains, the nitrate content dropped to 40 p.p.m., after which it remained at a low level throughout the remainder of the year.

THE RELATIONSHIP BETWEEN RAINFALL, SOIL MOISTURE CONTENT AND ACCUMULATED NITRATE NITROGEN FOR A SOIL IN UGANDA, EAST AFRICA.



This effect of mulch is one which has been frequently reported, as for instance by Albrecht (3) and Albrecht and Uhland (4). It may be that the onset of the rains had provided favourable conditions for biological activity in the soil which, in the case of the bare soil, had stimulated nitrate production. Under the mulch, it had either failed to have this effect or else had resulted in consumption of nitrate during the decomposition of the mulch.

Correlation of nitrate changes with rainfall, moisture and temperature

A fair positive correlation exists between nitrate and rainfall ($r = +0.42 : N = 46$). As a natural corollary, a similar negative correlation exists with soil temperature. It is difficult to accept that this latter conclusion is valid to the extent that low nitrate production is correlated with high temperatures and *vice versa*. Temperatures under mulch were often more than 10° C. lower than on the bare plots, whilst moistures were considerably higher. It seems obvious that rainfall can only exert its effect through soil moisture. There would seem to be an interplay of factors such as soil moisture, soil temperature, hours of sunshine and possibly others more obscure. It is hoped during the work which is now being planned to lend more precision by installing a recording rain gauge and by making nitrate determinations at more frequent intervals.

Nitrate accumulation at lower depths

Quantitative determinations have not been made below 12″, but in the middle of October, qualitative (brucine) tests for nitrate were made down to three feet. These showed that a high nitrate content persisted in the bare soil to this depth. In the absence of evidence to the contrary, the increase at lower depths may be taken to be due to downward movement from the upper layers.

The difference between mulched and bare soil persisted to the depth examined. This fact is somewhat remarkable in view of the narrowness of the alternate strips and illustrates strikingly the absence of lateral movement of nitrates.

The nitrate changes at 6–12″ in the bare plots followed those at 0–6″, though they were less in magnitude and with less sharply-defined maxima. Nitrates at 6–12″ on the mulched plots were to all intents identical throughout with those at 0 – 6″.

Source of the nitrate

Among many of the questions which arise from these preliminary observations, the most important is, what is the source of the nitrate formed ?

The suggestion is current that large quantities of nitrate-nitrogen occur in the rain water itself under tropical conditions. Unpublished figures for Kawanda, for which we are indebted to Dr. W. S. Martin, show that the nitrate content of the rain water amounts to about 1 lb. per ten inches of rainfall per acre, a negligible quantity in comparison with the actual amounts accumulated. Occasional determinations during the course of the present work bear this out.

If the soil organic matter is the source of the nitrate, the quantity of the latter manufactured through the season on the bare plots (300 p.p.m. or more) should have reduced appreciably the soil organic nitrogen. Reduction has not been found to have occurred during the present season but the enquiry continues.

As a corollary to the question of where the nitrate originates, is that of, what is its fate when it disappears ? The answer may be found in the downward movement (see above), though, since the diminution occurs with the slackening of the rains, diffusion is suggested rather than leaching.

Conclusions

The results of the year's observations indicate clearly that, under the conditions at Kawanda (medium rainfall and medium-textured soil), a considerable accumulation of nitrate-nitrogen occurs on bare soil during the rainy seasons. This accumulation is equivalent in amount to a very heavy dressing of a nitrogenous fertiliser. There is an unexplained diminution during the dry periods. Under a grass mulch, nitrate content is appreciably lower than that for bare soil.

Post Script : Subsequent to the abandonment of the experiment described in this article, and after a year's run, the bare strips were mulched and the previously-mulched strips received no more mulch and soon became bare. Nitrate was subsequently determined in the soil under the reversed treatments, with the following results :—

Date	Mulched strips (previously bare) (NO_3-N; p.p.m.) 0-6 ins.	6-12 ins.	Bare strips (previously mulched) 0-6 ins.	6-12 ins.
At change-over	130	115	20	25
Feb. 28 (after a long dry period)	107	61	40	37
Mar. 7 (after 0.01 ins. rain)	192	21	94	14
„ 21 (after 0.72 ins. rain)	113	144	90	15
Apr. 4 (after 4.45 ins. rain)	5	26	84	24

NOTE: The reversal of "bare" for "mulched" treatments clearly results in a large loss of nitrate from the mulched soil, previously bare, when heavy rainfall follows a period of dry weather, and in an appreciable increase in nitrate in the bare soil, previously mulched, under the influence of light rainfalls.

References

1. Ann. Rep. Dept. of Agriculture, Uganda, 1934, p. 92.
2. The significance of carbon-nitrogen ratio in soils growing cotton; *III*, Hardy, F., *Trop. Agric.* 23, No. 11, p. 209. Nov. 1946.
3. Nitrate accumulation under a straw mulch. Albrecht, W. A., *Soil Sci.* 14 (1922), p. 299.
4. Nitrate accumulation under a straw mulch. Albrecht, W. A. and Uhland, R. E. *Soil Sci.* 20 (1925) p. 253.

Received for publication, April, 1949.

FURTHER OBSERVATIONS ON THE "UNKNOWN DISEASE" OF COCONUTS

By

E. B. MARTYN, B.A., A.I.C.T.A.

(Plant Pathologist, Department of Agriculture, Jamaica.)

Introduction

The very serious diseases of coconuts which occur intermittently throughout the Caribbean area have of recent years been the subject of extensive investigation, particularly in Jamaica and Trinidad. It is thirty years or more since the Phytophthora Bud Rot of coconuts and the Red Ring disease, due to eelworms, were recognised as distinct from another and more widespread type of disease, which in general began with nutfall, soon followed by the death of the heart and the whole crown, and which became epidemic over considerable areas where coconuts grow closely. Subsequent investigations in Trinidad suggested that this latter type of disease was non-parasitic, and the name Bronze Leaf Wilt was applied to it. More recent observations in Jamaica indicated that the explanation of the disease put forward by the Trinidad workers was not applicable to Jamaica (Martyn 1945a), and it was eventually shown that the disease in the South Caribbean and that in the North, though similar in some respects, were not in fact identical, and since the cause still remained a mystery, the name 'Unknown Disease' was given to the latter (Leach, 1946). Detailed descriptions of this disease and its distribution have been given by Martyn and Leach. As regards its distribution it may be noted that recent information has been received of the occurrence of what appears almost certainly to be the same disease at several points on the Caribbean Coast of Panama and Central America.

Nature of the disease

Failure to find a parasite associated with the initial stages of the disease, and of all attempts to transmit the disease artificially, together with the fact that although epidemic within certain areas, it remained confined to these, suggested that it was non-parasitic. Leach suspected a minor element deficiency, and some preliminary analyses suggested a lack of manganese as a cause, but Innes (1949) has shown this not to be the case, and the occurrence of the disease on very varied soil types, both acid and alkaline, supports the unlikelihood of a soil factor being the primary cause. At the conclusion of his investigations a visit to Haiti caused Leach somewhat to revise his previous opinion as to the non-parasitic nature of the disease.

The writer has now had the disease under observation in Jamaica for over eight years. Its distribution as seen at first was compatible with a non-parasitic cause. Though the tendency of the main spread, on the coast of Hanover, had been from east to west, this was not universal, and the disease was not found west of Pedro Point. During the last five years, however, it has progressed steadily westward along the coast, always from diseased areas to healthy, reaching to Green Island and beyond, until now it has reached Orange Bay at the west end of the Island, where it had been observed already in 1946 at Bloody Bay. It had been recognised inland and on the South Coast many years before (Martyn 1945a).

Coconuts are not uniformly numerous along the north-west coast, plantations or shoreside groves alternating with areas in which only scattered palms appear. The progress of the disease in this area during recent years, however, has been quite regular. Some six months or a year after the disease in one plantation has become epidemic, one or two cases will appear

amongst the few palms in the area between this and the next regular cultivation to the west. Then after a further interval, scattered cases will be seen at the eastern end of the next plantation or grove. This will be followed by the increase of the disease to epidemic proportions, the intensification proceeding steadily from east to west through the plantation. (In one typical case a strip of coconuts about ½ a mile in length by ¼ mile wide at Cousins Cove showed the first cases in August 1944 and was virtually wiped out by May 1947.) The process then repeats itself, and so the disease creeps steadily along the coast. It is thus apparent that the progress of the disease in recent years along the north-west coast of Hanover cannot be explained except on the assumption that it is infectious. No non-parasitic environmental cause would become evident in this manner, but would at first appear uniformly scattered in an area where similar conditions prevailed, becoming intensified throughout it as time went on.

The distribution and spread of the disease is not always, however, as straightforward as has been described above, and presents many puzzling features. In Hanover, though making rapid spread on the flat lands bordering the coast and in the mouths of the valleys, it is less regular in its appearance among the more scattered coconuts of the hilly land behind the coast, in some valleys becoming quite widespread in recent years (e.g. Lucea, East River), but in others, apparently similar, making as yet no headway (e.g. Lucea, West River). Also, it is by no means so serious on limestone soils. In north-east Trelawny what is apparently the same disease (though minor differences in symptoms are observable) occurs on shallow soil immediately overlying limestone. Scattered cases occur under these conditions, and where coconuts are plentiful, sufficient instances may appear in a plantation to cause alarm, yet the disease here never assumes epidemic proportions or spreads with the rapidity observed in Hanover. Furthermore, on the Hanover coast, where coconuts occur on elevated limestone near the coast, with level land of other soil types between the limestone and the sea, the disease is widespread and typically epidemic on the soils of the flats, but it is only very occasional in its occurrence on the *immediately* adjoining limestone slopes.

Though forced to the conclusion that the disease is infectious, it is another matter to assign a cause. It must be attributable to an organism or a virus, and the known facts suggest that the method of entry into the plant is by the root system. Leach noted the quite frequent unilateral appearance of the symptoms on mature palms in the early stages of the disease, nuts often falling on one side of the palm for a month or more before they start to fall on the other. Such would be compatible with the entry of the disease at one point of the root system only. Furthermore, the initial symptoms involving nut fall in mature palms, coupled with a breakdown of young tissues in the inflorescence where growth is taking place, and the breakdown of the growing point, suggest that some substance of a toxic nature is carried to these tissues by the conducting vessels of the palm.

In a young non-bearing palm early symptoms of the disease include the drying out of the still folded heart leaf, due to the death of the tissue at the base of it, near the growing point, which may occur even before the outer leaves start to yellow. The manner of death of this young heart tissue in the 'cabbage' rather suggests that it had mortified as a result of toxic action and then became subject to the attack of saprophytic bacteria, which must always be present in the heart, however close packed the tissues, resulting in the subsequent evil-smelling rot of the 'cabbage'. There is nothing to suggest the initial entry of an organism from outside, which would of necessity either be accompanied by some form of external lesion, or would in the first instance affect only certain portions of the crown, as in the case of Phytophthora Bud Rot, or the Bacterial Bud Rot of palms which has been observed in Mauritius (Orian, 1947).

An insect vector carrying a virus disease is unlikely to be able to penetrate the growing point or young inflorescence tissue within a closed spadix, where primary symptoms occur, and in any case the irregular spread of the disease as described above, and its widely dissimilar intensity on very closely adjoining but different soil types make it appear unlikely that a virus carried by an air-borne vector is responsible, even if it is assumed that such a virus only retains its viability for a very short time within the vector. In addition, the confinement of the disease for many years to certain areas only, in the territories where it is known to occur, make such a cause appear improbable.

When the roots are considered, however, the symptoms of the disease do not suggest the presence of an organism killing them. Apart from the fact that no parasitic organism can be discovered in the roots in the early stages of the disease, the death of coconuts resulting from killing of the root system assumes a different form. If the roots of a palm are severed, or if the entire root system is killed by gas oil, the resulting symptoms are similar to those of Drought Wilt (Martyn 1945b), the outer leaves drying out and withering in regular succession, the heart remaining alive long after the older leaves are dried and dead, and being the last part to die. In a plot where the disease was

epidemic, the growth rates of young palms have been observed at regular intervals, so that in a number of instances it was possible to forecast the appearance of the disease by the cessation of growth before external symptoms could be observed (Leach). Examination of the lighter coloured, younger roots of such palms shows the presence of more starch in the cortex than in healthy roots, and sometimes the formation of thyloses in the vessels, and some initial entry of fungi into the cortex — *i.e.* symptoms indicating that these organs are rapidly becoming moribund. Within a week of this, however, the heart symptoms are visible. An organism causing a root disease in the generally accepted sense would be present in the tissues for some time, where it should be visible on examination, and would result in wilt symptoms. The symptoms that do in fact occur are more suggestive of the absorption, presumably through the roots, of some substance of a virus or toxic nature which initially causes cessation of growth in the youngest and most rapidly growing tissues, followed by the death of these, and the internal changes which result in the yellowing of the oldest leaves.

Considering the possibility of a virus as the cause of the disease, which if its infectious nature is accepted and no causal organism can be found seems to be the only alternative solution, the unlikelihood of one carried by an air-borne vector has already been indicated. It may also be noted here that attempts at transmission of the disease by pricking with needles and the use of abrasives have been negative. It is, however, conceivable that a disease of a virus nature might be carried by a soil-borne organism, and such a theory would be supported by the rapidly epidemic nature of the disease when it starts on certain soil types where coconuts are growing close together. On the other hand, attempts to transmit the disease by burying soil and root debris from newly diseased plants around the roots of healthy plants have failed to secure infection.

Experiments are now in progress in which coconuts are being grown in tubs, some containing soil from areas where the disease is rampant, others soil of another type from a part of the island where the disease has never occurred. These have been set up in two areas, one where the disease has occurred and no coconuts remain, and another where it is still prevalent. Coconuts have also been set out in the soil adjoining the stands bearing the tubs. These experiments may throw some light on whether or not the disease originates in certain soil types and whether or not it can be air-borne.

The disease is of a baffling nature, and the comparatively slow growth and eventual bulk of the coconut make it a difficult subject for experiment. The impossibility of grafting a plant of this nature further handicaps exploration of a possible virus cause. It may be noted here that the mysterious nature of the disease, and its virulent effect on the coconut, have certain features in common with the 'Quick Decline' of citrus, as it has become manifest in different parts of the world. Whatever may be the ultimate solution, however, it seems likely that if the problem of the Unknown Disease can be solved, further light will thereby be thrown on the Bronze Leaf Wilt disease of the Southern Caribbean, hitherto attributed solely to non-parasitic causes and ascribed to 'Physiological Wilt', and it is desirable that the two diseases should be studied with reference to each other.

Summary

(1) A short account is given of the history of the Unknown Disease of coconuts and its investigation to date.

(2) Evidence is presented that the disease is of an infectious nature.

(3) The possible nature of the disease is discussed.

(4) A short description is given of experiments on the disease now in progress.

References

Innes, R. F. (1949). The manganese content of leaf and inflorescence tissue in relation to the "Unknown Disease" of the coconut palm in Jamaica. *Trop. Agriculture* 26 : 57 - 60.

Leach, R. (1946). The Unknown Disease of the coconut palm in Jamaica. *Trop. Agriculture* 23 : 50 - 60.

Martyn, E. B. (1945a). Coconut diseases in Jamaica I. *Trop. Agriculture* 22 : 51 - 59.

Martyn, E. B. (1945b). Coconut diseases in Jamaica II. *Trop. Agriculture* 22: 69-76.

Orian, G. (1947). Bud Rot of the royal palm in Mauritius. *La Revue Agricole de l'Isle Maurice* 26 : 223 - 258.

Received for publication, February, 1949.

A FURTHER INVESTIGATION IN THE CONTROL OF THE TRINIDAD FROGHOPPER (TOMASPIS SACCHARINA DIST.) BY APPLICATION TO THE NYMPHS OF A 4% BENZENE HEXACHLORIDE DUST

By

T. E. K. Potter & A. J. Carrington,

(Agricultural Department of T. Geddes Grant Ltd., Trinidad.)

Introduction

A report issued by the writers (1) in October 1947, on the effect of soil application of a 3.5% benzene hexachloride — (BHC) — dust ("Agrocide 2") in froghopper nymph control, indicated that such a treatment afforded complete protection for a period of 3 months against nymphal infestation. It was not ascertained whether the chemical was functioning as an ovicide, or if the nymphs were being killed upon emergence from the egg by coming in contact with the benzene hexachloride in the soil. However, the work done by Dr. H. C. James (2) suggested that the control effect of the chemical was probably ovicidal in addition to being that of contact.

In the latter part of the 1947 froghopper season Mr. Gooding of Caroni Estate observed that the application of "Agrocide 3" dust — (containing 5% BHC) — to froghopper nymphs in spittle masses, in and around the base of a few cane stools, appeared to effect complete mortality.

Shortly after, Mr. J. Mayers of Reform Estate applied this insecticide in a similar manner to one acre of a field heavily infested with froghopper adults and nymphs. Previously the whole field had received numerous applications of "Agrocide 3" by the drift-dusting technique in an attempt to control the adults, but the single stool-application of insecticide resulted in complete absence of nymphs for the remainder of the season within the treated area.

On account of these findings it was considered most advisable that the method of applying benzene hexachloride dust to the nymphs in and around the base of cane stools should be carefully investigated, and accordingly the experiment hereinafter described was planned and executed during the 1948 froghopper season at Reform Estate.

In order that the full significance of the results of this experiment should be appreciated, a brief summary of the bionomics of the sugar cane froghopper is given.

Bionomics of the Froghopper

The Trinidad sugar cane froghopper — *Tomaspis saccharina* Dist. — is a member of the order Hemiptera, family Cercopidae.

Urich (3), Urich and Pickles (4), Pickles (5), are responsible for the main contributions to our knowledge of the life-history of this insect. However, the main points of interest arising from this work, in so far as this attempted method of control is concerned, are the following :

Under average conditions of weather, the nymphs appearing soon after the onset of the wet season in May — termed 1st brood nymphs — are emergences from the accumulated total of "long-period" eggs laid by 2nd, 3rd and 4th brood adults of the preceding year. 1st brood adult females lay only "short-period" eggs, which give rise only to the 2nd brood infestation.

The froghopper nymph feeds on the sugar cane rootlets on, or near to, the surface of the soil, in, and immediately around, the cane stool. The nymph has four moults or four instars, which occur during a period of from 24-27 days.

From this it is evident that if 1st brood nymphs can be effectively controlled, subsequent broods will not appear, and complete control of the pest will be achieved.

A description of the experiment to determine the effectiveness, or otherwise, of varying application rates of a 4% benzene hexachloride dust on 1st brood froghopper nymphs, follows :

Nymphal control experiment

Site

Reform Estate, Field No. 34. Variety B. 37161, 3rd ratoons.

Layout

The experiment was laid out in the form of four 4 x 4 latin squares, there being 4 treatments, each replicated sixteen times.

Plot size

The sizes of the plots were 20′ x 19.5′ or 390 sq. ft. each, the whole experiment covering an area of nearly 2/3rds of an acre in the south-eastern corner of the field.

Treatments

The four treatments comprised :

0 = No treatment.
1 = 1 cwt. per acre rate of a 4% benzene hexachloride dust.
3 = 3 cwts. per acre rate of a 4% benzene hexachloride dust.
6 = 6 cwts. per acre rate of a 4% benzene hexachloride dust.

Insecticide

The insecticide used was a 4% benzene hexachloride dust made by diluting one part "Agrocide 7" (a Plant Protection Ltd.'s product containing 20% BHC or 2.6% gamma BHC) with 4 parts of ground limestone of 100 — mesh fineness.

Application

The dust was applied by means of a Root rotary hand duster in and around the base of the cane stools, confined as far as possible to the nymph-infested area. The treatment can more aptly be described as a "spot application", and it is estimated that approximately only 1/5th of the total soil surface area was covered with the insecticide. Neither the area around the stool nor the stems were cleaned before application, but the field was fairly clear of trash as it had been burned before reaping.

Nymphal counts

As far as possible the actual number of nymphs — (not spittle masses) — per stool were counted and a thorough search was made in cracks and trash for nymphs. Two stools per plot, selected at random, were counted on each occasion, and during the period of the trial from 30/6/48 to 19/10/48, eight separate counts were made. An effort was made not to kill the nymphs when counting. Also, recently counted stools were avoided on subsequent checks.

Duration of experiment

The first count was made on the morning of June 30th, after which the insecticide was applied. Thereafter, counts were made on the following dates :

July 2nd, 6th, 27th.
August 17th.
September 7th and 28th.
October 19th.

Details and results

In table I results of nymphal counts are summarized. Line (3) shows the total mean number of nymphs per stool for the four treatments on the various days of counting. The differences between the means per stool for the count before insecticidal application, and the means per stool for subsequent counts are shown in line (4). Line (5) shows the population trends expressed as percentages of the first day's count. Line (6) shows the nymphs per stool to be anticipated if no treatment had been applied. These anticipated population figures are computed from the pre-treatment populations in the treated plots and the populations trends shown in line (5) for the untreated plots. Line (7) shows the actual mortalities, these being the percentage differences between anticipated populations, — line (6) —, and actual populations after dust application — line (3).

In figure I are plotted the percentages given in table I line (5) and therefore this is a graphical comparison of the nymphal populations for treated and untreated plots. For the sake of clarity, the figures for the 6 cwt. per acre treatment are not plotted since they approximate closely to those for the 3 cwt. per acre treatment.

Observations

(1) Although the experimental lay-out was so designed to allow of a statistical analysis being applied to the results, this was considered unnecessary on account of the most definite, and by inference, significant, figures obtained.

(2) From the table and figure supplied, it is apparent that the Agrocide formulation used, (containing 4% BHC), has executed a definite and prolonged control of froghopper nymphs within the experiment.

(3) There would not appear to be any significant differences between the three rates of application of the 4% BHC powder, as all effect a control of over 90% for a period of 3 months at least — see table I line (7).

(4) It was unfortunate that the nymphal populations within the untreated plots commenced a permanent decline after the 4th counting on the 48th day, on account of which the insecticidal action is not so marked thereafter. However, from the bionomics of the insect, within the first 48 days of the experiment there must have been at least one mass egg-hatching, other than the one responsible for the nymphs found on the first day. This is supported by the figures supplied in table I, line (5), whereby it is shown that in the untreated plots a net nymphal population of over 60% above that found on the first day was maintained up to the forty-eighth day. During the same period, population figures for the treated plots are at a steady minimum, being approximately 95% below the initial day's count.

Thereafter, although the population in the untreated plots fell below that of the initial day, it was still comparatively much higher than

FIGURE I

COMPARISON OF NYMPHAL POPULATIONS

IN TREATED & UNTREATED PLOTS

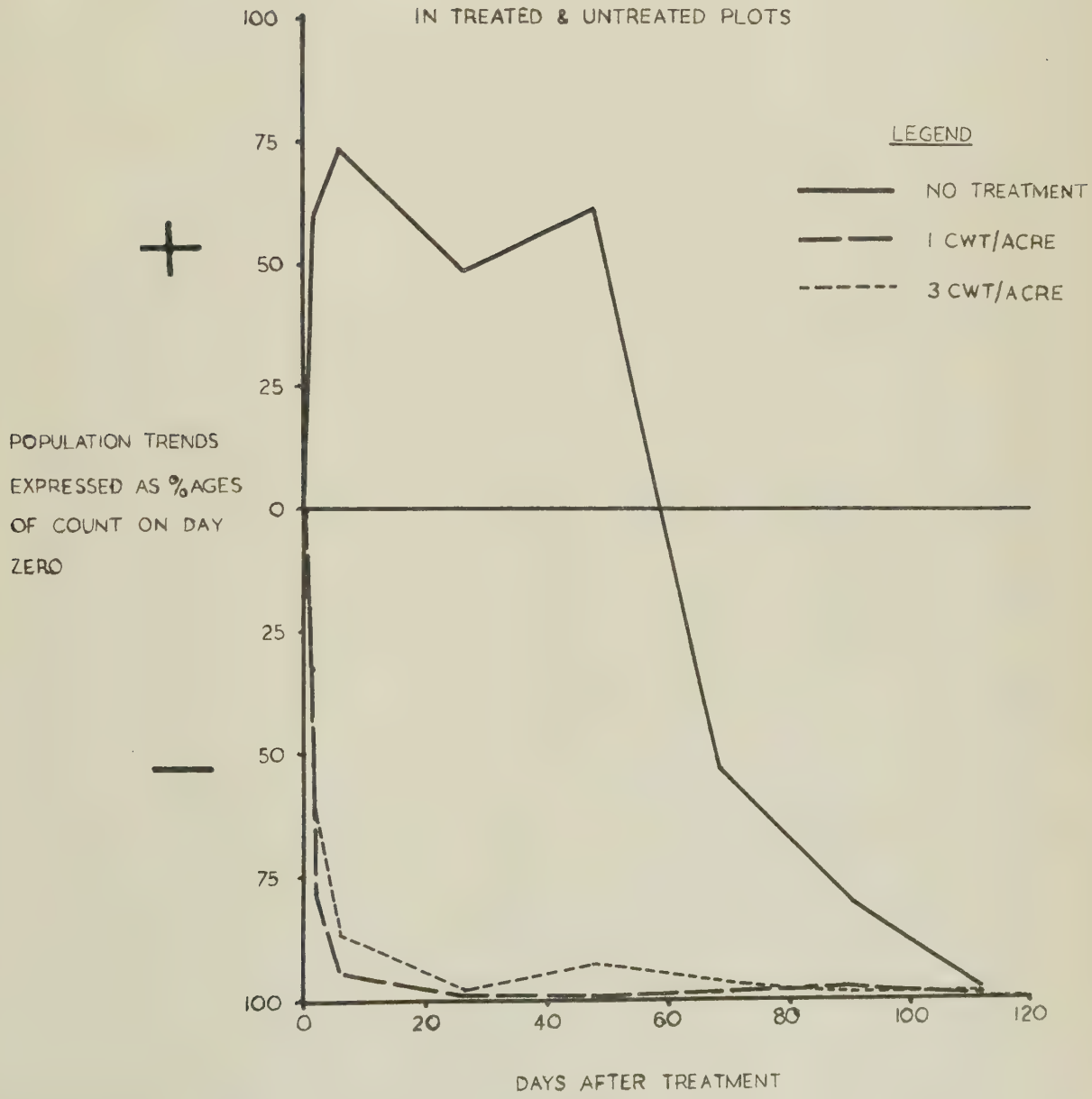


TABLE I

SUMMARY OF NYMPHAL COUNTS, BY TREATMENTS ON RESPECTIVE DATES

TREATMENTS — —	(O) — No Treatment								(1) — 1 cwt. 4% BHC							
(1) Days after Treatment	Before	2	6	27	48	69	90	111	Before	2	6	27	48	69	90	111
(2) Date of Count	30/6	2/7	6/7	27/7	17/8	7/9	28/9	19/12	30/6	2/7	6/7	27/7	17/8	7/9	28/9	19/10
(3) Total Mean per stool	10.3	16.5	17.8	15.3	16.7	4.9	2.0	0.25	12.1	4.8	1.6	0.3	0.9	0.5	0.16	0.06
(4) Difference in population per stool		+ 6.2	+ 7.5	+ 5.0	+ 6.4	— 5.4	— 8.3	— 10.05		— 7.3	— 10.5	— 11.3	— 11.2	— 11.6	— 11.94	— 12.04
(5) Population trends. Line (4) expressed as a percentage		+ 60.2%	+ 72.8%	+ 48.5%	+ 62.1%	— 52.4%	— 80.6%	— 97.6%		— 60.3%	— 86.8%	— 97.5%	— 92.6%	— 95.9%	— 98.7%	— 99.5%
(6) Anticipated mean nymphs per stool, if no treatment.										19.4	20.9	18.0	19.6	5.8	2.4	0.3
(7) Actual Mortalities due insecticide. Percentage from lines (3) & (6).										75.3%	92.3%	98.3%	95.4%	91.4%	95.3%	80.0%

TREATMENTS — —	(3) — 3 cwts. 4% BHC								(6) — 6 cwts. 4% BHC							
(1) Days after Treatment	Before	2	6	27	48	69	90	111	Before	2	6	27	48	69	90	111
(2) Date of Count	30/6	2/7	6/7	27/7	17/8	7/9	28/9	19/10	30/6	2/7	6/7	27/7	17/8	7/9	28/9	19/10
(3) Total Mean per stool	14.0	2.9	0.75	0.03	0.03	0.19	0.34	0.0	12.7	1.3	0.3	0.0	0.09	0.03	0.12	0.03
(4) Difference in population per stool		— 11.1	— 13.25	— 13.97	— 13.97	— 13.81	— 13.66	— 14.0		— 11.4	— 12.4	— 12.7	— 12.61	— 12.67	— 12.58	— 12.67
(5) Population trends. Line (4) expressed as a per centage.		— 79.3%	— 94.6%	— 99.8%	— 99.8%	— 98.7%	— 97.6%	— 100%		— 90.0%	— 97.6%	— 100%	— 99.3%	— 99.8%	— 99.1%	— 99.8%
(6) Anticipated mean nymphs per stool, if no treatment		22.4	24.2	20.8	22.7	6.7	2.7	0.3		20.3	21.9	18.9	20.6	6.1	2.5	0.3
(7) Actual Mortalities due insecticide. Percentage from lines (3) & (6).		87.0%	96.9%	99.8%	99.8%	97.2%	87.4%	100%		93.6%	98.6%	100%	99.5%	99.5%	95.2%	90%

those of the treated plots, and, by field observations, this difference was being maintained by new egg emergences on a limited scale, within the untreated area.

These figures suggest that there could be an operative residual effect by the insecticide, support for which may be found in the maintenance of an actual mortality of over 80% by all applications up to the 111th day.

(5) The decline in nymphal population within the untreated plots can most probably be attributed to the fact that the remainder of the field in which the experiment was located, and in fact all fields with nymphal populations on the estate, had received an application of 2 cwts. per acre of the identical "Agrocide" formulation. For this reason, the population of adults over the entire area was negligible, and as the relative area of untreated soil was minute, the possibility of maintaining an active population in the untreated plots was remote.

(6) It has been stated that the cane within the experiment was not trashed nor weeded before treatment was applied. This was possible because of the fact that the area had been burned before reaping during the 1948 crop, and consequently there was not much trash in and around the stools. Whether similar results could be reproduced in an area with heavy trash is an open question, but it is improbable that the lowest application — viz : 1 cwt. per acre of a 4% BHC dust — would be as effective under such conditions.

(7) As described, the dust was applied to the base of the cane stools by means of a Root rotary hand duster. The use of a manually operated unit for such a purpose is subject to criticism, and there are disadvantages as well as advantages to such a method of application.

Disadvantages

(a) The method is comparatively slow and the efficiency of application is subject to the vagaries of labour.

(b) As it cannot be expected that 1 boy could apply the insecticide to more than 1 acre per day (8 hours), the cost of application will be relatively high.

(c) The ideal time for treatment (June) coincides with the greatest demand for labour, (for weeding, fertilizer application, etc.)

Advantages

(a) The equipment necessary is inexpensive and within the economic limit of the smallest cane farmer.

(b) Unskilled labour can be employed under supervision in the dust application.

(c) Its use, as compared to mechanical distribution, favours the minimum application of insecticide.

(8) As no suggested method of control of any pest is of practical significance without some idea of the cost being given, some details on this point are included hereunder :

Cost

COST OF FROGHOPPER NYMPH CONTROL WITH AN "AGROCIDE" FORMULATION CONTAINING 4% BENZENE HEXACHLORIDE (BHC)

(1) *Material*

1 part of "Agrocide 7" (containing 20% benzene hexachloride — BHC) — to 4 parts pulverised limestone of 100 — mesh fineness, to make an "Agrocide" formulation containing 4% BHC.

Cost of diluted powder, inclusive of labour in mixing, depreciation of mixing unit, etc. ..... 5.3 cts. per lb.

(2) *Equipment*

Cost of average hand duster $30.00
Estimated depreciation charges, etc., on duster, makes cost per acre, on basis of 1 duster treating 42 acres per year for 3 years 0.24

(3) *Labour*

(a) Cost of applying — 1 man per acre — (basis 1 cwt. per acre) ..... $1.37 per acre.

Transporting materials & incidentals 0.25 per acre.

Total : $1.62 per acre.

For the three rates of application used, the following will be the comparative costs, per acre :

	1 cwt.	*3 cwts.*	*6 cwts.*
Material :	$ 5.94	$17.82	$35.64
Equipment :	0.24	0.24	0.24
Labour :	1.62	2.16	3.24
	$ 7.80 per ac.	$20.22 per ac.	$39.12 per ac.

If it is determined to be necessary to trash and clean the stools before application, the relative costs will be increased to :

1 cwt. per acre rate — $12.15 per acre.
3 cwts. per acre rate — 24.57 per acre.
6 cwts. per acre rate — 43.47 per acre.

If the significance of "1st brood" froghopper nymph control is now applied, it is probable that complete froghopper control is being attained at a cost of:

1 cwt. per acre rate — under 2 tons of cane per ac.
3 cwts. per acre rate — under 4 tons of cane per ac.
6 cwts. per acre rate — under 6 tons of cane per ac.

Conclusions

(1) The results of the experiment above-described have demonstrated that 1st brood froghopper nymphs were completely controlled during the 1948 froghopper season within the area of experiment, by application of an "Agrocide" dust formulation containing 4% benzene hexachloride.

(2) There was no significant difference between the mortality rates effected by application of 1 cwt., 3 cwts. and 6 cwts. per acre of this "Agrocide" formulation on the nymphs.

(3) Whether on account of the complete control attained on the 1st brood nymphs, or on account of the extraordinary residual toxicity known to be possessed by "Gammexane" gamma BHC in the soil, complete froghopper nymph control was maintained within the treated area, throughout the entire duration of the experiment — viz: 111 days.

(4) The method of control attempted has been shown to be both practical and economical, and applicable both to large estates and small cane farmers.

(5) It is too early for exaggerated claims to be made, but apart from the possibility of froghopper egg control, the described method suggests that a practical, economic and effective means of controlling the sugar cane froghopper in Trinidad has been determined.

Acknowledgements

The writers acknowledge their indebtedness to the following:

(a) The management of Reform Estates (1928) Ltd., for their permission to lay down the experiment on their property and supplying labour.

(b) Plant Protection Ltd., London, for making available supplies of "Agrocide 7", free of charge, for use in the trial.

(c) Mr. J. C. Mayers, Chemist, Reform Estate, whose observations and initiative were responsible for the trial being made; whose co-operation and assistance in laying out the experiment, organizing a counting staff, and the other many details involved in such a trial, made the experiment possible.

(d) Mr. J. A. Potter, Field Superintendent, Ste. Madeleine Sugar Co., Ltd., and his staff, who assisted in making the counts, and who contributed also in arriving at the cost figures.

References

(1) Potter, T. E. K., and Carrington, A. J., — 1947. Report on a preliminary investigation of the effect of soil application of "Gammexane" formulations on sugar cane froghopper incidence. T. Geddes Grant Ltd., Port-of-Spain (private circulation).

(2) James, Dr. H. C., — 1947. Report on experiments to determine the ovicidal efficiency of "Liquid Agrocide 3", ("Gammexane") on the eggs of Tomaspis flavilatera, Ur., the Demerara sugar cane froghopper, conducted at Plantation L.B.I., Demerara. Department of Agriculture, British Guiana (private circulation).

(3) Urich, F. W., — 1913. The sugar cane froghopper and biological notes on some Cercopids in Trinidad. Board of Agriculture, Trinidad and Tobago, circulation No. 9.

(4) Urich, F. W., and Pickles, A., — 1930. Studies in the incubation of eggs of the sugar-cane froghopper. *Minutes and Proceedings, Sugar-Cane Investigation Committee, Vol. III,* pp. 64 — 70, 253 — 255.

(5) Pickles, A., — 1933. Entomological contributions to the study of the sugar-cane froghopper, parts I and II. *Tropical Agriculture, Vol. X,* pp. 222 — 233, 240 — 243, 286 — 295.

Received for publication, January, 1949.

VESICULAR-ARBUSCULAR MYCORRHIZA IN SEA ISLAND COTTON AND OTHER TROPICAL PLANTS

BY

A. JOHNSTON *

Introduction

A large volume of literature on mycorrhiza has accumulated since the first important contribution by Frank (1885), who realized the possibility of its symbiotic nature. Much is now known about the occurrence, significance, morphology and physiology of the ectotrophic mycorrhiza of conifers and other trees, the ectendotrophic mycorrhiza of Ericales, and the endotrophic mycorrhiza of orchids and other plants with abnormal nutrition. The common vesicular-arbuscular type has received less detailed attention, mainly due to the virtual impossibility of obtaining pure cultures of the fungus concerned. It is not known, for example, whether the endophytes of different higher plants belong to one or many fungal species. There is, however, some evidence that two unrelated fungi, a Phycomycete and a member of the Fungi Imperfecti, may at times occur together in the same root, producing the normal characteristics of vesicular-arbuscular mycorrhiza. Similarly, little is known of the part played by the fungus in the nutrition of the higher plant. Descriptions of this type of mycorrhiza have been given by Janse (1896–7), Butler (1938–9) and others, while lists of mycorrhizal and non-mycorrhizal plants have been published from time to time; the first by Schlicht (1888) (Germany); others by Janse (*loc. cit.*) (Java), Mc Dougall and Liebtag (1928) and Thomas (1943) (U.S.A.), Asai (1934) (Japan) and Neill (1944) (New Zealand).

Previous work on mycorrhiza in Trinidad was almost entirely restricted to cacao (*Theobroma Cacao* L.) (Pyke, 1935; Laycock, 1945). The present investigation falls into two main sections: (1) a general survey to find the distribution, morphological variation and intensity of the mycorrhizal association in a sample of the flora, including plants of different habit and environment; (2) a more detailed investigation of mycorrhiza in Sea Island cotton (*Gossypium barbadense* L.). In connection with the latter, plants were grown in different soils to discover if the mycorrhizal fungus was affected by this factor, as suggested by the work of Rayner (1939) on Indian cotton and that of Reed and Frémont (1935) on orange. A pot experiment was also devised to compare the growth of Sea Island cotton with or without mycorrhiza.

General Survey

All the plants examined are either indigenous to Trinidad or introduced crop plants. Only a very small sample of the total flora could be studied, but a number of different types were included. Examination was limited to the absorbing rootlets, as only these showed mycorrhiza. With practice it was usually possible to recognize mycorrhizal roots by their general appearance. They are yellowish or light brown in colour, in contrast to the whiter uninfected roots, and often of greater diameter. Material was examined fresh when possible, corresponding samples being fixed and preserved in formol-acetic-alcohol for further study. Longitudinal sections were found superior to transverse, these being cut by hand, stained in cotton blue-lactophenol and mounted in lactophenol.

Two types of vesicular-arbuscular mycorrhiza were distinguished, but as attempts to isolate the fungus were unsuccessful, it is impossible to say whether these are distinct, or merely phases of the same association. They differ in the mode of disintegration of the fungus in the root cells. In the first, called here the "sporangiolar" type, there is very little penetration of the outer cortical cells of the root, the fungus in this region being largely intercellular. In the cells of the cortex next to the endodermis the fungus becomes differentiated into intracellular arbuscules, borne on short branches of the intercellular hyphae (Fig. 1). These are often very numerous, occurring in almost every cell of this layer. When young, an arbuscule is usually seen as a solid deeply-staining mass, with a coarsely granular surface, almost completely filling the cell; later, it becomes more aggregated towards the centre of the cell, stains less readily, and assumes a more irregular shape. The final form is a solid refringent nodule remaining attached to the intercellular hypha by its stalk. In the second type, termed "intracellular hyphal", these structures are not formed. The hyphae rarely penetrate far into the root before beginning to ramify and coil inside the cells, and in some instances almost every cell of the cortex may be occupied by fungus (Fig. 2). The coiled hyphae in several layers of cells finally disintegrate; they gradually lose their clear-cut outlines and break into shorter pieces (Fig. 2), then

* Adapted from a dissertation submitted in part requirement for the Associateship of the Imperial College of Tropical Agriculture (A.I.C.T.A.).

aggregate into a more solid mass, and finally become homogeneous and granular (Fig. 2 & 3). Similar vesicles occur sporadically in both types of mycorrhiza (Fig. 4).

The 93 plants examined are listed below, grouped according to habitat. The degree of mycorrhizal development is indicated by arbitrary figures: (4) all roots infected, with the fungus abundant throughout; (3) all roots infected, with the fungus present throughout, but not extremely abundant anywhere; (2) all or most roots infected, though not heavily, and parts of them without fungus; (1) infection rare, occurring only in a few roots, or in very small patches in several; (0) mycorrhiza absent. The sporangiolar and intracellular hyphal types are denoted by (a) or (b) respectively; in some forest trees both were found (ab).

Weeds of roadsides and recent cultivation: *Borreria verticillata* (L.) Meyer, *Scoparia dulcis* L., (4b); *Capraria biflora* L., *Euphorbia hirta* L., *Malachra alceifolia* Jacq., *Sida stipulata* Cav., *S. rhombifolia* L., *Stachytarpheta jamaicensis* Vahl, (3a); *Axonopus compressus* P. Beauv., *Bidens pilosa* L., *Desmodium adscendens* (Sw.) DC., *Heliotropium indicum* L., *Piriqueta cistoides* (L.) Meyer, (2a); *Caladium bicolor* (Ait.) Vent., *Croton hirtus* L'Hér., *Solanum stramonifolium* Jacq., (2b); *Priva lappulacea* Pers., (1b); *Amaranthus spinosus* L., *Argemone mexicana* L., *Commelina elegans* H.B.K., *Dichromena ciliata* Vahl, *Momordica Charantia* L., (0).

Species of regenerating waste land ("secondary bush"): *Browallia demissa* L., *Cordia curassavica* (Jacq.) R. & S., *Heliconia psittacorum* L.f., *Genipa americana* L., *Ochroma lagopus* Sw., (4b); *Eupatorium odoratum* L., (3a); *Croton* sp., (3b); *Hamelia erecta* Jacq., (2a); *Cecropia peltata* L., *Clindemia* sp., *Lantana Camara* L., (2b); *Costus* sp., *Duggena hirsuta* (Jacq.) Britton, *Piper* sp., (0).

Forest trees: *Alchornea glandulosa* Poepp., *Protium guianense* (Aubl.) March, (4ab); *Tectona grandis* L., *Terminalia dichotoma* G. F. W. Mey., (4a); *Andira inermis* H. B. K., *Didymopanax Morototoni* Dcne. & Pl., *Pentaclethra macroloba* (Willd.) Kuntze, *Sterculia caribaea* R. Br., (4b); *Mora excelsa* Benth., (3ab); *Calophyllum antillanum* Britton, (3a); *Byrsonima spicata* Rich., (3b); *Carapa guianensis* Aubl., (2ab); *Eschweilera subglandulosa* (Steud.) Miers, (2b).

Orchard savannah species; found on impoverished sandy soil: *Hyptis lantanaefolia* Poit., (4b); *Cissus erosa* L. C. Rich., (3a); *Elephantopus angustifolius* Sw., (2a); *Amasonia campestris* (Aubl.) Moldenke, *Xylopia aromatica* (Lam.) Mart., (2b); *Clibadium surinamense* L., (1b); *Paspalum virgatum* L. (1 — unrecognizable as either type); *Lisianthus chelonoides* L.f., (0).

Crop plants: *Canavalia ensiformis* DC., *Canna edulis* Ker.-Gawl., *Carica Papaya* L., *Citrus paradisi* Macf., *Manihot utilissima* Phl., *Theobroma Cacao* L., (4b); *Cajanus cajan* (L.) Millsp., *Hibiscus esculentus* L., *Phaseolus Mungo* L., *Urena lobata* L., (3a); *Crotalaria juncea* L., *Dioscorea alata* L., *Vigna unguiculata* (L.) Walp., (3b); *Gossypium barbadense* L., (2a); *Citrus aurantifolia* (Christm.) Swingle, *C. sinensis* Osbeck, *Maranta arundinacea* L., *Panicum maximum* Jacq., *Solanum Melongena* L., *Zea Mays* L., (2b); *Crotalaria usaramoensis* E. G. Baker, *Glycine max* (L.) Merrill, (1a); *Capsicum annuum* L., *Coffea liberica* Hiern., *Indigofera endecaphylla* Jacq., *Musa* sp., (1b); *Saccharum officinarum* L. (1 — unrecognizable as either type); *Bambusa vulgaris* Schrad., *Brassica oleracea* L. (cauliflower), *Mangifera indica* L., *Oryza sativa* L., (0).

Seashore plants: *Cocos nucifera* L., (3a); *Canavalia maritima* (Aubl.) Thou., (3b); *Egletes prostrata* (Sw.) Kuntze, *Wedelia trilobata* (L.) Hitchc., (1a); *Philoxerus vermicularis* (L.) Nutt. (1 — doubtfully mycorrhizal; fungus possibly parasitic).

Table I

Distribution, type and intensity of mycorrhiza in species of different ecological habitats

Ecological Group	Mycorrhizal spp. %			Mean intensity
	type (a)	type (b)	Total	
Weeds	50.0	27.3	77.3	2.0
Secondary bush	14.3	64.3	78.6	2.4
Forest	*53.8	*76.9	100.0	3.5
Orchard savannah	25.0	50.0	‡87.5	1.9
Crop plants	22.6	61.3	‡87.1	2.1
Total (93 spp.)	*34.4	*52.7	‡86.0	2.3

* Includes species with both types of mycorrhiza.
‡ Includes species unrecognizable as either type.

Table I summarizes information given in the lists. Data for seashore species is included in the totals, but the number of species examined in this group was too small to warrant the calculation of separate percentages. The type of mycorrhiza is denoted as before, and figures for mean intensity are evaluated from those indicating mycorrhizal intensity in individual species. The largest proportion of mycorrhizal species occurred amongst the forest trees, these also showing the greatest intensity of infection. Classifying all species as herbs, shrubs or trees, the mean intensity of infection was found to be

1.9, 2.1 and 3.1 respectively. Weeds and secondary bush had fewest species with mycorrhiza, although over 75% of the plants in these groups were infected. Weeds were unique in being more often infected by the sporangiolar type. The species found with vesicular-arbuscular mycorrhiza occur in 26 families of the Dicotyledons and 7 of the Monocotyledons. Of those families in which 5 or more species were examined, Malvaceae, Leguminosae, Compositae, Euphorbiaceae and Verbenaceae gave no negative species. In the first-named all 9 species showed only sporangiolar infection, while the 4 remaining families included examples of both this and the intracellular hyphal type.

Mycorrhiza in Sea Island Cotton

Influence of Soil Conditions on Mycorrhizal Development

In the survey only general differences in habitat were considered. To obtain more exact data on the influence of soil factors on vesicular-arbuscular mycorrhiza, more detailed work was done on Sea Island cotton, which has the sporangiolar infection. Plants were grown in soils of 3 types: A, poor soil, shown by analysis to be a light sand, neutral to slightly alkaline, low in organic matter and nitrogen and very deficient in available phosphate and potash; B, the same soil enriched by the addition of half its volume of pen manure, to give a soil rich in organic matter and nutrients; C, the same soil enriched by suitable amounts of ammonium sulphate, calcium phosphate and potassium chloride, to give a soil lacking in organic matter but equivalent to B in available nitrogen, phosphate and potash.

The development of mycorrhiza in roots from the 3 soils was assessed by radial longitudinal sections, stained in cotton blue-lactophenol. Its presence or absence was recorded in a number of young roots, 6 of which were selected at random for further study. The proportion of their total length infected was calculated, as a percentage, from measurements with an eye-piece micrometer. If fungus appeared on both sides of the stele, this part of the root was considered fully mycorrhizal; if on one side only, its length was halved when calculating the percentage length infected. The ratio of arbuscules to hyphae was also assessed, by assigning to both 5 arbitrary degrees of incidence. Table II summarizes the results obtained.

Table II

Incidence of mycorrhiza in cotton roots from 3 soil types

Soil type	% Roots infected	% Length infected	Arbuscules / Hyphae
A. Poor sandy soil	90	15.9	1.05
B. Do. + pen manure	90	93.4	1.16
C. Do. + artificials	69	24.7	0.84

In poor soil, the mycorrhizal fungus was present in almost all roots, but infected areas were localized and small. Hyphae and arbuscules were almost equally common. Addition of pen manure produced abundant infection, with arbuscules more common than hyphae. This agrees with results from the general survey, which disclosed the greatest mycorrhizal intensity in forest soils, which are rich in organic matter. With the addition of inorganic salts, fewest roots contained the fungus, and in these it was little more abundant than in poor soil. The ratio of arbuscules to hyphae was low. Yellowish discoloration and large spherical inclusions were seen in several cells containing hyphae, suggesting interference with cell contents. This was very rare in poor soil and was not found at all in the organic matter treatment.

Effect of Mycorrhiza on Growth in Different Soils

A pot experiment was devised to compare growth of cotton with and without mycorrhiza in the three soils described above. Each soil was used: 1, untreated; 2, sterilized, and 3, sterilized but re-inoculated with the mycorrhizal fungus. Plants were grown singly in six-inch pots and each treatment comprised 8 plants. Soil in treatments 2 and 3 were steam-sterilized for 20 minutes, and pots were sterilized with 3% formalin. In treatment 3, the mycorrhizal fungus was re-inoculated by adding, just below the seeds, 15 cc. of soil from around the roots of cotton plants known to possess mycorrhiza. When 11 weeks old, all plants were examined for mycorrhiza and those not as planned discarded. The remainder were uprooted, cleaned, dried at 105° C. and then weighed. Table III gives mean treatment dry weights for the three soils. It also gives results of statistical comparisons between treatments, analysed separately for each soil. Figures in brackets indicate the number of plants from which means were calculated, and the different soils and treatments are denoted as above.

Table III

Effect of the treatments on dry weight of cotton plants grown in different soils

Soil	Treatment	Mean dry wt. in gms.		Differences between means	
A	1 (8)	2.68	0.86*		0.67
	2 (6)	1.82			
	3 (6)	3.35	1.53*		
B	1 (8)	8.73	2.56*		4.21*
	2 (8)	6.17			
	3 (3)	4.52	1.65*		
C	1 (8)	7.39	1.10		2.73*
	2 (8)	6.29			
	3 (5)	4.66	1.63		

* Significant at 5% probability level.

In poor soil, best growth was obtained in the presence of mycorrhiza, sterilized soil being inferior to both unsterilized soil and that sterilized but with mycorrhizal inoculum added. The mean dry weights of plants in the last-named treatments were not significantly different, indicating that sterilization had not materially altered the nutrient status. For soil rich in organic matter, growth was best in unsterilized mycorrhizal soil, but poorest in that sterilized and re-inoculated. In a subsidiary experiment with a different soil, also rich in organic matter, sterilized with formalin, a similar result was obtained. No significant benefit from the presence of mycorrhiza was shown in the soil enriched by inorganic salts but low in organic matter; but this also, unsterilized, gave better growth than when sterilized and re-inoculated. This adverse effect of sterilization, in soils rich in nutrients, may have been due to a great increase in the soil microflora which often follows re-infection, these abnormally numerous organisms rendering nutrients unavailable to the higher plant. Whatever the cause, it renders the results less conclusive with regard to the importance of mycorrhiza. Nevertheless, the latter was beneficial to cotton plants, up to 11 weeks old, when grown in poor sandy soil, and possibly to those in soil rich in organic matter; whereas in the presence of plentiful nutrient salts but little organic matter, it had no significant effect on growth.

Summary

Vesicular-arbuscular mycorrhiza occurred in 86% of species examined in a representative sample of the Trinidad flora. Although it was common in each of the 6 ecological habitats surveyed, the proportion of mycorrhizal species and the intensity of infection varied; both were greatest in forest soils of comparatively high organic matter status. Mycorrhizal species were least common amongst herbs or shrubs growing as weeds of cultivation or constituents of "secondary bush". Two types of endophyte were recognised, differing in the mode of degeneration of the fungus in root cells. These are termed the "sporangiolar" and "intracellular hyphal" types. The latter was commoner in all groups of plants examined, except weeds.

In Sea Island cotton, mycorrhiza was affected by the soil, that with abundant organic matter being most favourable to its development. A pot experiment showed that mycorrhiza was not essential for growth in young cotton plants, but varied in importance with soil conditions. It was beneficial in poor soil and possibly in that rich in organic matter, whereas in the presence of plentiful inorganic nutrients and little organic matter it had no effect.

References

Asai, T. (1934). Über das Vorkommen und die Bedeutung der Wurzelpilze in den Landpflanzen. *Jap. J. Bot. 7,* 107.

Butler, E. J. (1938-39). The occurrences and systematic position of the vesicular-arbuscular type of mycorrhizal fungi. *Trans. Brit. mycol. Soc. 22,* 274.

Frank, A. B. (1885). Ueber die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. *Ber. dtsch. bot. Ges. 3,* 128.

Janse, J. M. (1896-7). Les endophytes radicaux de quelques plantes Javanaises. *Ann. Jard. bot. Buitenz. 14,* 53.

Laycock, D. H. (1945). Preliminary investigations into the function of the endotrophic mycorrhiza of *Theobroma Cacao* L. *Trop. Agric., Trin., 22,* 77.

McDougall, W. B. & Liebtag, C. (1928). Studies in a deciduous forest. III. Mycorrhizal relations. *Bot. Gaz. 86,* 226.

Neill, J. C. (1944). Rhizophagus in Citrus. *N. Z. J. Sci. Tech.,* A, *25,* 191.

Pyke, E. E. (1935). Mycorrhiza in cacao. *Rep. Cacao Res., Trin., 1934,* 41.

Rayner, M. C. (1939). The mycorrhizal habit in crop plants, with a reference to cotton. *Emp. Cott. Gr. Rev. 16,* 171.

Reed, H. S. & Frémont, T. (1935). Factors that influence the formation and development of mycorrhizal associations in *Citrus* roots. *Phytopathology, 25,* 645.

Schlicht, A. (1888). Ueber neue Fälle von Symbiose der Pflanzenwurzeln mit Pilzen. *Ber. dtsch. bot Ges. 6,* 269.

Thomas, W. D. (1943). Mycorrhizae associated with some Colorado flora. *Phytopathology, 33,* 144.

Received for publication, September, 1948.

THE USE OF DYNAMITE IN LIFTING BAMBOO CLUMPS FOR PROPAGATION

BY

R. H. Hageman, R. Ferrer Delgado, and N. F. Childers *

Bamboo is being used extensively in soil conservation practices and also by the furniture, fishing rod, and novelty industries established by the Puerto Rico Development Company. The growing demand for bamboo is illustrated by the fact that in 1946 only 8,195 rhizomes (1) were distributed throughout the island of Puerto Rico by the Federal Experiment Station while in 1947 the total reached 17,381 (2). A major problem in propagating bamboo has been the expensive and time-consuming process of digging the rhizomes by hand. The need for a more rapid and cheaper method of removal has become imperative as the demand increases.

The rhizomes of most bamboo clumps grow close together and the fibrous roots intermingle forming a firm mass of soil and roots. A rhizome or clump division can be defined as the minimum amount of root and stump that can be transplanted to establish a new clump of bamboo. It was suggested that properly placed charges of dynamite might blow the saucer-shaped clump of stumps and roots completely free. Trials were made to determine the feasibility of this method.

The following method partially illustrated in Fig. 1, was found satisfactory for completely blasting out the rhizomes of the bamboo clumps. Holes each 1½ inches in diameter and equally spaced with a minimum interval of 18 inches were made around the circumference of the bamboo clump using a soil auger or a pointed, tapered, steel rod. The holes were dug to a depth of 30 inches, slanted at a 45° angle and pointed towards the centre of the clump so that the dynamite was directly beneath the clump divisions. In some trials two or more sticks of dynamite were placed in alternate holes instead of digging a greater number of holes. Experience is the best guide in determining the location and number of holes and whether one or two sticks of dynamite per hole will be necessary to do a thorough job. In these trials electric detonating caps † and 40 per cent dynamite were prepared and fired according to instructions given in the Blaster's Handbook (2). After the charges were emplaced the wires of the caps were then connected in series to a long lead wire and fired by means of a blasting machine. One cap is all that is necessary to fire one or more sticks of dynamite per hole.

The data of these trials presented in table 1 give an idea of the amount of digging, dynamite, and caps required to remove various sized clumps of bamboo rhizomes. It is evident from these data that it is important to use an adequate amount of dynamite to blow the entire clump clear on the first blast. Each succeeding blast becomes less effective because of the loosened soil and air space around the clump. The number of caps used is also an index of the number of holes dug. Final results obtained by adequate and properly placed charges are shown in Fig. 2. These pictures show that the individual clump divisions are accessible for rapid and easy removal with machete or axe.

Cost comparisons are difficult to make because the dynamiting technique is new and not sufficiently established to become routine. Also the number of trials made were not extensive enough to establish the minimum charge necessary to remove the small clumps. These trials did establish the following information presented in table 2.

* R. H. Hageman, Chemist, R. Ferrer Delgado, Collaborating Agronomist, Government of Puerto Rico, and N. F. Childers, formerly Assistant Director, Federal Experiment Station, U.S. Department of Agriculture, Mayaguez, Puerto Rico.

† The use of detonating cord in place of the majority of the electric detonating caps is suggested on the basis of simplicity and safety factors.

Table 1. — The amount, cost, and relative effectiveness of dynamite and electric blasting caps used to excavate bamboo clumps of different sizes.

Bamboo	Offsets per clump	Area of clump	Caps used	Sticks of dynamite used	Cost of dynamite and caps	Blasts	Results
Variety	*Number*	*Sq. ft.*	*Number*	*Number*	*Dollars*	*Number*	
B. tulda (new) (1)	89	48	13	18	4.83	3	clump completely loosened but not blown clear.
B. tulda (new)	73	80	12	16	4.36	4	clump completely loosened but not blown clear.
B. tulda (new)	134	46	9	16	3.91	1	clump blown clear of hole.
B. tulda (new)	133	50	7	9	2.43	1	,, ,, ,, ,, ,,
B. tulda (old) (2)	50	42	8	9	2.58	1	,, ,, ,, ,, ,,

(1) *Bambusa* Sp. P.I. No. 74413.

(2) *Bambusa tulda* Roxb. P.I. No. 21002.

Table 2. — A comparison of the cost and time required to excavate bamboo rhizomes by dynamite to manual digging.

Bamboo	DYNAMITING				DIGGING			
	Time required to emplace explosives	Average time per offset	Total (1) cost	Average cost per offset	Time required to dig	Average time per offset	Total (1) cost	Average cost per offset
Variety	*Man-Hrs.*	*Man-Hrs.*	*Dollars*	*Cents*	*Man-Hrs.*	*Man-Min.*	*Dollars*	*Cents*
B. tulda (new) (150 clump divisions) (2)	12.0	5.0	6.91	4.5	56.0	22.0	14.00	9.0
B. tulda (old) (50 clump divisions) (3)	6.0	7.0	4.07	8.0	16.0	19.0	4.00	8.0

(1) Cost of labour calculated at 25 cents per hour.

(2) Small clumps.

(3) Large clumps.

These data indicate that the use of dynamite especially on the larger clumps required the expenditure of one-fourth the man-hours and was one-half as expensive as hand-digging. On the smaller clumps the use of dynamite reduced the hand labour to one-third, though the total cost was slightly greater than digging by hand. It is possible that small clumps may be excavated with fewer sticks of dynamite and electric caps than used in this trial.

The dynamite blast did not damage the bamboo, as the entire mass clung tightly together and was lifted out in a solid saucer-shaped chunk. In general, not over one or two clump divisions were shattered per clump. The clump divisions that were blasted out, sprouted and grew as well when planted as did those that were dug by hand.

Literature Cited

1. White, D. G. and Huyk, J. B.

   1947. Bamboo production and industrialization. Puerto Rico (Mayaguez) Fed. Expt. Sta. Rpt. 1946 : 34.

2. .....

   1947. Bamboo production and industrialization. Puerto Rico (Mayaguez) Fed. Expt. Sta. Rpt. 1947 : 60.

3. Technical Division, E. I. Du Pont de Nemours and Company.

   1942. The Blaster Handbook. Explosive Department. Wilmington, Delaware. 11th Edition.

Received for publication, August, 1948.

A SIMPLE MATHEMATICAL PROCEDURE FOR USE IN CURING VANILLA TO A DESIRED MOISTURE CONTENT

BY

CARLOS F. CERNUDA

(Soils Conservation Service Research Project, Puerto Rico).

Vanilla pods, besides undergoing the enzymatic action responsible for the bio-chemical processes which occur during curing, also lose a great part of their original fresh weight as water. A loss of water is necessary to prevent the development of mold.

A great deal of time and labour is spent in determining moisture contents during different periods of the curing process. The usual procedure of reducing the fresh weight of beans by an assumed fraction is a hit and miss procedure, which may give poor results. The experiments of Arana and Kevorkian (1) were supplemented with a nomograph by Jones (1) who used essentially the same principle that is discussed here. Figures obtained experimentally by these workers serve as a basis for the present interpretation. The present formula has been worked out with the object of offering a simple method of computation, accurate enough for practical purposes.

The dry matter content of the fresh beans does not vary appreciably during the curing process. Water vapour is the main constituent loss, since the volatilization of any flavouring or aromatic constituent is negligible.

According to experiments previously made at this station (2) the average moisture contents of vanilla beans at different stages of maturity were as follows :

Stage of Maturity	Moisture	Dry Matter
	Per Cent	*Per Cent*
Beans green in colour	81	19
Beans with blossom ends yellow or beans that have just begun to split	79	21
Split beans with chocolate-coloured blossom ends	77	23
Split beans, chocolate-coloured all over	74	26

In these experiments it was also found that the loss in weight of beans during conditioning in closed boxes is as follows : For 20 to 30 per cent moisture in the final product, from .01 to .03 pounds are lost for each pound of fresh beans ; for 30 to 40 per cent moisture, from .04 to .07 pounds are lost for each pound of fresh beans.

The amount of water lost from each pound of fresh beans during conditioning is more or less constant for each particular moisture content desired in the cured product. This loss of water increases gradually with cured beans of greater moisture content. The ratio of percentage of dry matter in the fresh beans to percentage of dry matter in the cured beans is also constant for each of the four different stages of maturity. In each of these stages a factor common for beans cured to different moisture contents is obtained by adding the corresponding loss of water to these ratios of dry matters corresponding to different stages in maturity. In any case, the weight of the fresh beans divided by the corresponding factor gives the weight to which fresh beans should be reduced at the drying stage to bring cured vanilla beans to the desired moisture content after conditioning.

The following derivation explains mathematically the procedure previously discussed :

If . . . .

W_1 = Original fresh weight of beans.

D_1 = Percent dry matter in fresh beans.

W_3 = Weight of cured beans (conditioned).

D_3 = Percent dry matter in cured beans.

W_2 = Desired weight of beans at drying stage.

W_0 = Weight of water lost during conditioning for each pound of fresh beans.

(1) Arana, F. E. and Kevorkian, A. G. Relation of moisture content to quality of vanilla beans. Jour. Agr. Univ. Puerto Rico 27 : 105 - 116, illus. 1943.

(2) Arana, Francisca E. Vanilla curing. Puerto Rico (Mayaguez) Fed. Expt. Sta. Cir. No. 25, 7 pp. 1945.

Then

(Equation I) $W_1 D_1 = W_3 D_3$

The weight of cured beans	will be	the difference between desired weight of beans at drying stage	weight of water lost during conditioning
W_3	=	W_2 —	$(W_0)\ (W_1)$

Substituting in Equation I

$$W_1 D_1 = [W_2 - (W_0)\ (W_1)]\ D_3 = (W_2 - W_0 W_1)\ D_3 \text{ and}$$

(Equation II) $W_1 \frac{D_1}{D_3} = W_2 - W_0 W_1$

In Equation II, $\frac{D_1}{D_3} = K$, where K is a constant for each stage of maturity.

Then

$$KW_1 = W_2 - W_0 W_1$$

$$W_2 = KW_1 + W_0 W_1$$

(Equation III) $W_2 = W_1 (K + W_0)$

For beans cured to any moisture content ranging from 20 to 40 percent, W_0 will acquire values from .01 to .07, and

$$W_2 = \frac{W_1}{F}, \text{ where } F = \frac{1}{K + W_0}$$

These factors (F) are presented in table 1. Note that a different constant is needed for fresh beans at different stages of maturity.

Table 1. — Factors for calculating the reduction in weight of vanilla at the drying stage necessary to bring cured vanilla beans to the desired moisture content.

Desired moisture content in cured beans	Green beans	Blossom-end yellow or beans just beginning to split	Split beans with chocolate-colored blossom ends	Split beans chocolate all over
Per Cent				
20	4.04	3.66	3.36	2.98
21	3.99	3.62	3.32	2.94
22	3.85	3.51	3.22	2.87
23	3.82	3.47	3.18	2.83
24	3.70	3.37	3.09	2.76
25	3.65	3.33	3.06	2.72
26	3.54	3.23	2.97	2.65
27	3.50	3.19	2.94	2.62
28	3.40	3.10	2.86	2.55
29	3.36	3.07	2.82	2.52
30	3.26	2.98	2.75	2.46
31	3.17	2.90	2.67	2.39
32	3.13	2.86	2.64	2.36
33	2.99	2.75	2.54	2.28
34	2.96	2.71	2.51	2.25
35	2.87	2.64	2.44	2.19
36	2.84	2.61	2.41	2.16
37	2.76	2.54	2.35	2.11
38	2.72	2.50	2.32	2.08
39	2.62	2.41	2.23	2.01
40	2.58	2.38	2.20	1.98

The following example illustrates how the method may be used: Suppose 50 pounds of green beans are to be cured to a moisture content of 25 per cent. From table 1, the factor for *green* beans to be cured to a moisture content of *25* per cent is 3.65. Therefore, 50 pounds of green beans will have to be reduced to $\frac{50}{3.65}$ or 13.69 pounds during the drying stage, to obtain cured pods of approximately 25 per cent moisture content after conditioning. The use of factors is a simple method to determine how much to dry fresh vanilla beans to a desired moisture content.

Received for publication, October, 1948.

SOME BOOKS ON TROPICAL AGRICULTURE PUBLISHED ON THE CONTINENT OF EUROPE DURING AND SINCE THE WAR

BY

G. B. MASEFIELD,

(Lecturer in Colonial Agriculture, Oxford University)

During the war, British scientific workers were necessarily to a great extent cut off from the productions of Continental publishing houses. Since the end of the war, these have become available in Britain together with a spate of pent-up material newly published in the liberated countries; and there is a real danger that important books on tropical agriculture may be overlooked by those interested in the subject in Britain, still more so in the Colonies. In these circumstances, an informal review of a number of outstanding works by one who has recently had occasion to try to bring himself up to date in this field, may be found helpful.

No claim is made that the books to be dealt with in this article comprise an exhaustive list; they certainly do not. But it may well be more useful to draw attention now to a number of certainly valuable works than to attempt completion in tracking down every possibly relevant title. The absence of a book from my list is no indication of its demerit; it merely means that I have been unlucky enough to miss it. Prices of books unfortunately cannot be quoted, owing to fluctuating exchanges. The present article deals only with books; pamphlets and articles in journals, however important, must be omitted because of their very great number; they are in any case to a large extent covered by abstracting services.

Germany

In Germany, as is not unnatural in the circumstances, publications on this subject have been conspicuous by their absence. An important exception, however, is the "Handbuch der tropischen und subtropischen Landwirtschaft" by G. A. Schmidt and A Marcus with 40 collaborators (many of them very well-known), published in two volumes by E. S. Mittler und Sohn, Berlin, 1943. Originally sold in Germany at 45 marks, this now appears to be available only in a photo-offset edition in America at 12 guineas. This work may be classed as a very comprehensive but conservative text-book of the whole subject, having the advantage of bringing together both the crops and the livestock of the tropics within a single book. It leans hard on data collected by German (and to a lesser extent, other continental) scientists, and makes little reference to experimental work in British colonies, but has the merit of including much information on some areas such as South America which are only sketchily treated in most British books. It also strikes one as being out-of-date on some subjects even for the year of publication; for example, soil erosion and soil conservation are very inadequately treated. While containing a great deal of valuable background material on general agriculture and the related sciences, one feels that the whole work might have been condensed without losing very much.

Holland

Many British readers are already familiar with "Science and Scientists in the Netherlands Indies", edited by P. Honig and F. Verdoorn, which was published in English in New York in 1945 by the Board for the Netherlands Indies, Surinam, and Curaçao, an organisation set up by the Dutch Government then in exile. This book, with its comprehensive articles on soils, livestock, cinchona, tobacco, rubber, etc., serves to bring one up to date on agricultural science in the Netherlands Indies. It contains references to many publications from Holland and provides on p. 465 a list of recent bibliographies on the Netherlands Indies, which may perhaps serve to excuse the reviewer from giving further names of the numerous Dutch publications which have a partial bearing on agriculture in the Indies. Separate mention must however be made of Professor C. H. Edelman's very important "Studien over de Bodemkunde van Nederlands-Indië", originally published at Wageningen in 1941, with a second edition in 1947. This compilation surveys comprehensively the present state of knowledge of all branches of soil science in the area, with an especially full treatment of mineral nutrition and manurial problems. The book must certainly not be overlooked by British workers in this field merely because it is published in Dutch. An English translation would however be very desirable.

It should also be mentioned that the book of another Dutch professor, E. C. Mohr, previously only available in Dutch or in German as "Die Boden der Tropen" (1934), was published in an English translation in America in 1944 as "The Soils of Equatorial Regions" (Edwards Bros., Ann Arbor, Michigan).

Belgium

Starting from the year 1939 in Belgium, that year saw the publication of R. Vandenput's "Notes sur les Principales Cultures du Congo Belge" by the Ministry of the Colonies. This

is a simple and abundantly illustrated descriptive account of all the main tropical crops, well suited to be of use to students who are beginning the study of the subject. J. P. Harroy's "Afrique, Terre Qui Meurt", published at Brussels in 1944, is a treatise drawing attention to the problems of soil erosion and soil degradation which has already been fairly extensively reviewed in British journals. Of the same year is M. Ferrand's "Phytotechnie de l'Hevea", jointly published at Gembloux by Jules Duculot and at Paris by "Librairie Agricole de la Maison Rustique". This is a comprehensive survey of the botany and cultivation of the rubber plant. While many references to work in the East are included, those aspects of production which are of current importance in Africa receive the fullest treatment; and there appears to be, for example, no mention of either concentrated or preserved latex in the section on preparation for export. Nevertheless, this work seems to be at present the most up-to-date book available on rubber production, and as a monograph on one product of the Belgian Congo is a worthy successor to R. M. Belot's "La Sericulture au Congo Belge", published by the Ministry of the Colonies in 1938.

Incidentally, the publishers of M. Ferrand's book also advertise in their list a book by J. Guillaume "La Canne à Sucre aux Antilles Françaises", but not having had the opportunity of acquiring a copy of this, I am unable to say whether its date of publication falls within the period covered by this review or is slightly earlier.

The records of the international agricultural conference at Yangambi in the Belgian Congo in 1947 have been published in Brussels by the I.N.E.A.C. as "Comptes Rendus de la Semaine Agricole de Yangambi" in two volumes. Containing more than 100 separate papers, these provide a storehouse of factual information and thoughtful survey of many aspects of agriculture in the African tropics.

"Les Tsé-Tsés" by E. Heigh (Brussels, Ministry of the Colonies, 1946) is a full account of the genus Glossina which will be of interest to the entomologist rather than to the stockman.

France

It is from France that the spate of publications appears to have been greatest. I would give pride of place to P. Gourou's "Les Pays Tropicaux" (Presses Universitaires de France, 1947) which, in spite of its rather general title is in fact almost wholly devoted to an analysis of the problems of tropical agriculture. Like so many of the papers in the "Semaine Agricole de Yangambi", it sets out with admirable Gallic lucidity an exposition of many principles which British workers, immersed in the detail of experimental work, often dimly feel but have not clearly formulated. Starting at the very beginning with emphasis on the fact that tropical soils are mostly poor and not rich, it takes the difficulties of tropical agriculture as its basis throughout in a thoroughly realistic fashion. There are some excellent maps, including one which shows densities of population in Nigeria, Tanganyika, and Malaya among other territories. An admirable introduction to the subject for students, this is another book that one would single out for recommendation to translators. By the same author is "L'Utilisation du Sol en Indo-Chine Française" (Hartman, Paris, 1940).

Of G. Aubert's "Les Sols de la France d'Outre-Mer", published in 1941, I regret that I have seen no copy. R. Furon's "L'Érosion du Sol" (Payot, Paris, 1947) is a full and scholarly treatment, written by a geologist, of the causes and incidence of soil erosion in all parts of the world; while devoting a small section to soil conservation, it does not go into the subject fully. It has some excellent illustrations, among which the photograph from French Somaliland of four goats all standing on their hind legs browsing off one tree, with another goat actually climbing the tree, is a masterpiece.

C. Noriot and H. Alliot's "La Lutte Contre les Termites" (Masson et Cie., 1947) is another recent book of which I have not yet seen a copy. G. Doutressoulle's "L'Élevage en Afrique Occidentale Française" (Larose, 1947) is a large book on an interesting subject, but is disappointing in many ways. It devotes much space to a detailed description of the different types and "races" of livestock found in French West Africa, but little to information about management and production. From it one learns that Karakul sheep have been successfully introduced into this area. It gives eight pages to the camel, but there still appears to be no book in which one can obtain a comprehensive account of this animal, especially as a milk producer. Both the books mentioned in this paragraph have appeared under the auspices of the Office de la Recherche Scientifique Coloniale.

That veteran worker, Professor A. Chevalier, has several new books to his credit. In "Revolution en Agriculture" (Presses Universitaires de France, 1946), he presents, under the guise of a historical perspective, many of the reflections of a lifetime of work concerning both European and colonial agriculture. In the attractive little series of pocket-sized books published under the general title of "Que Sais-je?", he is responsible for "L'Agriculture Coloniale" (1942) and "Le Café" (1944). He is also joint author of the following members of this series:

"Le Coton" by A. Chevalier and P. Senay (1944).

"Le Caoutchouc" by A. Chevalier and J. Le Bras (1945).
"Forêts Vierges et Bois Coloniaux" by A. Chevalier and D. Normand (1946).
"Les Fruits Coloniaux" by A. Chevalier and J. Leroy.
"Le Tabac" by A. Chevalier and F. Emmanuel.

I have not had the opportunity of seeing copies of all these, but if "Le Caoutchouc" is typical of the rest, a wonderful amount of information on the cultivation and trade in the product is compressed into a small space. The information in this book is very up-to-date, and the publishers (Presses Universitaires de France) have thus supplied the French public at small price with recent facts about wide sectors of tropical agriculture in a way that no other country has perhaps achieved since the war.

Portugal

Most British workers are regrettably ignorant of the excellent agricultural work which is being carried out in the Portuguese African colonies. The outstanding publication during the period is perhaps J. Gossweiler and F. A. Mendonça's "Carta Fitogeográfica de Angola", published at Lisbon at the end of 1939 under the imprint of the Ministry of the Colonies. This volume contains in a back pocket a plant-geographical map of the whole of Angola, with 240 pages of descriptive text and a number of excellent photographs of vegetation types. It should be in the hands of all those who are interested in ecological studies in the Rhodesias and other neighbouring British territories. Another important botanical work is F. A. Mendonça's "Contribuïçoes para o Conhecimento da Flora de Angola—Vol. I, Compositae" (Lisbon, Ministry of the Colonies, 1943). Dealing with one family in the flora of Angola, this is stated in the preface to be a preliminary study for later incorporation in the "Conspectus Florae Angolensis", a work of collaboration between Portuguese botanists and the British Museum, of which the first volume was published in 1937. For the Mozambique colony, it is only fair to mention, although not published in Portugal but in 1946 at Lourenço Marques, the monumental report of the Chief of the Agricultural Services on agriculture in Mozambique in 1940–44, which runs to three illustrated volumes totalling 905 pages. These give a completely documented account of agricultural production and research work in the colony during that period, illustrating clearly the parallelism of agricultural problems and their solution in British and Portuguese territories. Unfortunately in the accounts of experimental work, there is a lack of evidence (as so often with the work of continental scientists in Africa) of any adequate statistical control such as would satisfy present canons in British agricultural science. The maps in these volumes are excellent. One of them makes plain, for the first time so far as I am aware, the distribution of tse-tse flies in the Mozambique colony.

Since these dates, there appear to have been no further outstanding publications on tropical agriculture from Portugal, but the journal "Agros" maintains interest in the subject and is at present running a series of articles on colonial agriculture.

Italy

Among war-time publications from Italy, one must begin with "World Trade in Agricultural Products" by L. B. Bacon and F. C. Schloemer, published in English by the International Institute of Agriculture at Rome in 1940. This contains 1,102 pages of text and statistical tables. Italian authors appear not unnaturally to have dropped out of the picture as regards tropical agriculture, but interest in the subject is maintained by the "Rivista di Agricoltura subtropicale e tropicale". A publication by Dr. Palloni "I Contratti Agrari degli Enti di Colonizzazione in Libia" (Florence, 1945) deals with the economics of settling Italian colonists in Libya, and interest in the same subject has been displayed in articles in the journal mentioned above and in the "Rivista di Economia Agraria".

Received for publication, July, 1948.

MANURIAL EXPERIMENTS WITH PAPAW (CARICA PAPAYA)

BY

C. A. THOROLD,

(Gold Coast Department of Agriculture; formerly Plant Pathologist, Trinidad)

Introduction

In discussing the "mosaic" disease of papaw in Trinidad, Baker (1) refers to a suggestion that this might be a deficiency disease, although he adduces evidence which favours the view that "mosaic" is due to a virus and not to soil abnormalities. Nevertheless, it was believed that it might be valuable to observe whether there were any effects on disease incidence, resulting from manurial applications, and at the same time to observe their effects on yields. Adsuar (3, 5) has described what appear to be at least two distinct virus diseases in Puerto Rico and has shown them to be transmitted by the green citrus aphid (4) and by a leaf hopper (6) respectively. The Trinidad papaw "mosaic" appears to resemble what is referred to as "bunchy top" in Puerto Rico, but the Trinidad disease has not been transmitted by grafting nor by a vector, therefore its etiology is still obscure.

In giving advice on papaw culture in Florida, Wolfe and Lynch (7) recommended applications of as much as 2½ lb. of mixed fertilizer per plant every month. Therefore, it seemed likely that yields might also benefit in Trinidad, through manurial applications. The experiments now to be described were undertaken because there was no previous information as to the effects of fertilizers and manures on disease incidence, and yields of papaw fruit in Trinidad.

Methods

The experiments were carried out at the St. Augustine Experiment Station of the Department of Agriculture. Papaw seed was sown in boxes, and later the seedlings were transplanted into bamboo-pots or boxes, before planting in the field. In certain cases, "female" plants were substituted for "males" in the field, when flowering began and "sex" was thereby indicated.

A spacing of 3′ x 3′ was employed, except in one trial.

It is realised that this planting distance is much less than that generally adopted, Wolfe and Lynch (4) recommend a spacing of 8 to 10 feet. There were two reasons for the choice of such a close spacing as 3′ x 3′:—

(1) To reduce the amount of cultivation required, by achieving a dense canopy of leaves which would suppress weed growth.

(2) The likelihood of occurrence of certain diseases previously described by Baker (2) indicated that the original stand of plants might be reduced by root-rot and collar-rot. The effect on yields through loss of plants in this way was not likely to be as great at 3′ x 3′, as it would be with a wider spacing, because the surviving plants could take advantage of any additional space which might become available through failure of their neighbours.

There were four experiments, involving applications of manures and fertilizers. Earlier trials of papaw at St. Augustine had indicated that satisfactory growth was obtained when applications of pen-manure * were given at planting time. In the first experiment (I) this initial application was equivalent to about 5 lb. manure at each plant site. Later, it appeared likely that the basal application of pen-manure may have reduced some of the effects which might otherwise have been observable through fertilizer applications in the absence of pen-manure. Subsequently, much smaller quantities of pen-manure (about ½ lb. per plant) were given as basal applications, before planting the other trials (Experiments II, III and IV).

Each application of fertilizer consisted of equal amounts of ammonium sulphate, muriate of potash and superphosphate, equivalent to about 1 ton of total artifical fertilizer at the single level ($N_1P_1K_1$) or twice this amount at the double level ($N_2P_2K_2$). In Experiment III where organic manures were compared with artificial fertilizer, pen-manure was applied at the rate of about 10 tons per acre and coconut-meal * * at 5 tons per acre. In Experiment IV, pen-manure was applied at the rate of about 40 tons per acre. The number of applications given

* Local pen-manure varies so greatly that it is not possible to give representative analyses for this material In general, the nitrogen content does not exceed 2% on air-dry basis.

* * Analyses of local coconut-meal were kindly undertaken by the Soil Chemist. The composition on an air-dry basis, was found to be as follows:—nitrogen 3.75%; potash (K_2O) 1.87%; phosphate (P_2O_5) 0.167%; ash 5.23%; moisture 12.96%.

at the above rates are shown later in the relevant table (II).

External border-rows and internal guard-rows separated the plots.

The fruit was picked and weighed separately for each plot. Observations on the incidence of mosaic were made at fortnightly intervals.

Results

Experiment I was planted in September 1944 and ended in October 1946. The inorganic fertiliser applications were given once every month from January to September 1945, inclusive.

The first case of mosaic was observed in April, 1945, which was approximately six months from the time of planting. Subsequently, mosaic infection increased progressively, as shown in Table I. In the course of the succeeding period of eighteen months, from April, 1945, to October, 1946, every plant became infected. There were 61 vacant sites, caused through failure of the plants during the experiment, these "missing-plants" account for the discrepancy between total number of plants affected (299) and the total number of plant-sites (360).

TABLE I.

Incidence of "Mosaic" per Month in Experiment I

	Number of "Mosaic" Plants																			
	'45									'46										
Month of observation	Apr.	M	J	J	A	S	O	N	D	Jan.	F	M	A	M	J	J	A	S	O	Total
Treatment $N_0P_0K_0$	—	1	1	—	2	4	4	10	19	13	8	13	8	4	6	—	—	4	—	97
$N_1P_1K_1$	—	—	3	1	4	6	6	9	16	10	9	11	8	9	3	2	3	—	1	101
$N_2P_2K_2$	—	—	—	2	1	5	10	13	7	9	17	14	7	7	4	—	3	2	—	101
Total	0	1	4	3	7	15	20	32	42	32	34	38	23	20	13	2	6	6	1	299

All the plants became affected with mosaic, therefore there was no ultimate differential infection due to either of the three manurial levels, nor was it possible to detect (Table I), any consistent differences in the progress of infection from month to month, which could be attributed to the fertilisers or to lack of them.

Observations were not maintained for such long periods in subsequent experiments, nevertheless, "mosaic" disease occurred on all plots regardless of treatment. There were no significant differences in this respect either for different planting distances, when 3′ x 3′ spacing was compared with 6′ x 6′ spacing in Experiment II, or for organic manures as compared with inorganic fertilisers in Experiment III. In this connection, it should be emphasised that whereas there was considerable beneficial response to coconut-meal as regards yield (as shown below), the number of mosaic plants was highest, but not significantly so, in plots receiving this treatment. Similarly, in Experiment IV where a relatively heavy application of pen-manure was given (totalling the equivalent of 80 tons per acre) the number of mosaic plants was apparently increased. Relatively large applications of organic manures such as coconut-meal or pen-manure, would be expected to supply sufficient of any minor element to cause a reduction rather than an apparent increase of "mosaic", if such a deficiency was the cause of the disease.

The yields obtained under the different treatments are summarised in Table II.

TABLE II. Showing Spacing of Plants, Manurial Applications and Yields of Fruit in the Four Experiments (I, II, III and IV)

Experiment	I			II				III				IV	
*Nature and number of applications	$N_0P_0K_0$ (0)	$N_1P_1K_1$ (9)	$N_2P_2K_2$ (9)	$N_0P_0K_0$ (0)	$N_1P_1K_1$ (2)	$N_0P_0K_0$ (0)	$N_1P_1K_1$ (2)	$N_0P_0K_0$ (0)	$N_1P_1K_1$ 3.7	Coconut Meal (2)	Pen Manure (2)	$N_0P_0K_0$ (0)	Pen Manure (2)
Spacing	3′ x 3′	3′ x 3′	3′ x 3′	3′ x 3′	3′ x 3′	6′ x 6′	6′ x 6′	3′ x 3′	3′ x 3′	3′ x 3′	3′ x 3′	3′ x 3′	3′ x 3′
n yield per ent (lb.)	20.0	21.7	23.0	7.5	14.8	17.9	51.3	3.0	(2)	7.6	3.2	2.4	3.4
ical difference % point)	3.0			13.2				2.8				1.0	

* Additional to basal applications of pen-manure.

Table II shows that significantly higher yields were obtained with the artificial fertiliser combined with a wider spacing, and also with the use of coconut-meal.

Conclusions

The experiments described above, have demonstrated that the incidence of papaw "mosaic" disease cannot be reduced by manurial applications. However, it has been shown that yields can be increased by the use of coconut-meal and possibly also by artificial fertilisers.

Higher yields were obtained at the wider spacing (6′ x 6′); nevertheless, general observations suggested that the closer spacing (3′ x 3′) may be preferable for commercial practice, because the advantage of better yields may be offset by higher cultivation costs at the wider spacing. There was virtually no weed growth, after the first two months from planting, at the closer spacing (3′ x 3′). Another advantage in aiming at a large number of plants to the acre for commercial practice, is that there is not the same necessity for "supplying", unless the stand obtained at first planting is a very unsatisfactory one. An occasional failure, resulting in a spacing of six feet in a 3′ x 3′ planting, is not important, but at 6′ x 6′, an accidental spacing of twelve feet between the plants would be undesirable. It must be emphasised also, that there will be an inevitable toll of plants through "mosaic" disease, which is apparently unaffected by the spacing adopted. The loss of plants is proportionately more serious at the wider spacing.

Baker (2) has shown that it is possible to effect control of "mosaic" by cutting back, but this inevitably delays the fruiting of the plant and is no insurance against the possibility of the same plant apparently becoming re-infected later. It was found in the course of Experiment I, that the period of profitable bearing was limited to about ten months, because after that lapse of time the incidence of "mosaic" became so high that total yields diminished rapidly. It seems likely, therefore, that it will not generally be advantageous to control the disease by cutting back on the field scale, because of the resulting delay in fruiting. It seems to the writer, that the object should be rather to obtain the maximum possible stand at the first planting and to aim at rapid growth and high yields by one or two applications of complete artificial fertiliser at the rate of about one ton per acre.

Further experiments should be carried out on the use of coconut-meal, which appears likely to be a useful manure for papaw. At the time of writing, this material was in short supply in Trinidad, therefore its use could not be advocated.

Summary

(1) A description is given of experiments which were designed to determine the effects of manurial treatments on "mosaic" disease incidence and yields.

(2) The planting distance employed was 3′ x 3′ except in one experiment when three-foot and six-foot spacings were compared. Artificial fertiliser treatments were also included in this experiment.

(3) In another experiment, fertiliser was compared with two different organic manures (pen-manure and coconut-meal).

(4) Neither planting distance nor manurial treatment affected the incidence of mosaic disease.

(5) When combined with the use of artificial fertiliser yields were significantly higher at the wider (6′ x 6′) spacing. Nevertheless, reasons are given for preferring the closer spacing (3′ x 3′), and for recommending its use in commercial practice.

(6) Coconut-meal applied in two lots at the rate of about 5 tons per acre each, gave significantly increased yields. However, the use of coconut-meal could not be advocated because this material was not readily available locally.

(7) Reference is made to the procedure of cutting back for the control of "mosaic", but it is believed that this method may not be advantageous on the field scale, because of the delay in fruiting which results.

(8) It is recommended for commercial practice, that a spacing of 3′ x 3′ should be employed. It is important that a good stand of plants should be achieved at the first planting, because "supplying" is likely to be difficult and uneconomical.

(9) It is considered that rapid-growth and early fruiting are important objectives. It is recommended that one or two applications of complete fertiliser should be given at the rate of about one ton per acre.

Acknowledgement

The writer is indebted to Mr. J. C. Muir, O.B.E., for his interest in these experiments and in particular for his suggesting the use of coconut-meal.

References

(1) Baker, R. E. D., (1939) Papaw Mosaic Disease, *Tropical Agriculture,* 16, pp., 159-163.

(2) Baker, R. E. D., (1933) Papaw Root and Collar-Rot, *Tropical Agriculture,* 10, pp., 328-329

(3) Adsuar, J., (1946) Studies on Virus Diseases of Papaya (*Carica papaya*) in Puerto Rico. I. Transmission of Papaya Mosaic. *University of Puerto Rico Agric. Expt. Sta. Technical Paper* No. 1, pp., 1-10.

(4) Adsuar, J., (1946) II. Transmission of Papaya Mosaic by the Green Citrus Aphid (*Aphis spiraecola* Patch) *loc. cit., Technical Paper* No. 2, pp., 1-5.

(5) Adsuar, J., (1946) III. Property Studies of Papaya Mosaic Virus *loc. cit.* Technical Paper No. 4, pp., 1-11.

(6) Adsuar, J., (1946) Transmission of Papaya Bunchy Top by a Leaf Hopper of the Genus *Empoasa,* Science 103, No. 2671, p., 316.

(7) Wolfe, H. S., and Lynch, S. J., (1942) Papaya Culture in Florida, *Agricultural Extension Service Bulletin* 113, pp., 1-35.

Received for publication, March, 1948.

REVIEW

BANANAS *

There is little point in writing a book that is neither more comprehensive nor more accurate than those that have previously been written on the same subject. The present volume, in those aspects which the reviewer is competent to judge, achieves neither the thoroughness nor the accuracy which might be expected. Thus Chapter I implies that all Eumusas (instead of only some strains of two species) have edible fruits; and that the old binomials can still usefully be used for cultivated banana varieties despite the citation of a work on p. 1 which has effectively shown that they cannot be so used. Incidentally *M. paradisiaca* is wrongly spelt on pp. 2 and 4. The rest of this chapter and the next (II, Structure and development) are so sketchy as to be quite misleading; Skutch's important papers on the anatomy and morphology of Gros Michel are not even cited; plant physiologists will wonder what is meant by statements about control of transpiration in para. 1, p. 26; fig. 4, p. 27 is very bad indeed.

In subsequent chapters (III–VI, storage, ripening, transport, physiology of the fruit, nutritive value, etc.) the author evidently writes with a more direct knowledge but even here one feels that a critical selection of material for discussion might have made possible a clearer and more conclusive exposition. As it is, the bibliography is an imposingly useful one but one wonders whether the author has any conclusions of his own on the many problems set forth — he hardly helps the reader to arrive at any.

In Chapter VIII banana diseases are treated inaccurately in 13 pages; Wardlaw dealt with the matter very satisfactorily in several hundred and his book is not even cited. The proposal on p. 156 to treat cigar end rot by removing the pistal (sic) and perianth of the female flower soon after emergence will hardly be taken literally. Chapter IX is notable for the useful Tables 49–51 which, however, are misquoted on p. 11.

There are a good many minor errors and spelling mistakes, some of which have been noted above. The book is very well made and printed.

N.W.S.

* Bananas by H. W. von Loesecke. Interscience Publishers, New York and London, 1949. Pp. 189, with 51 tables, 29 figures in the text and 1 coloured plate. (Economic Crops Vol. I).

THE OCCURRENCE OF PHASES IN INSECTS OTHER THAN LOCUSTS

In 1921 Uvarov advanced, as a working hypothesis, what has come to be known as the Phase Theory of Locusts. Subsequent field observations and laboratory experiments by a number of entomologists have completely corroborated his main assumptions and the phase theory is now accepted as a proved biological fact.

Briefly, the theory postulates that the true locusts, *i.e.*, the gregarious and migratory species of Acrididæ, exist in a series of forms differing from one another both in structure and habits :— to such an extent that, prior to the acceptance of Uvarov's theory, the different phases of many locusts were regarded as entirely distinct species, the solitary phases not being considered as "locusts" at all.

The *phasis solitaria* is not gregarious and does not form migratory swarms, but lives very much like an ordinary grasshopper and consequently causes very little damage. The nymphs of this phase are very variable in colour, which tends to resemble that of their environment. The adults have a rather elongate pronotum which is somewhat arched, has a distinct dorsal keel, and is without a lateral constriction. The hind femora are comparatively long and the fore wings comparatively short : the insect is thus more adapted for a life on the ground than for prolonged flight.

The *phasis gregaria* is the swarming and migratory phase which does such immense damage. The nymphs tend to be conspicuously coloured, mainly black and yellow or orange, irrespective of the colour of their environment. In the adults the pronotum is shorter than in the solitary phase, flat or slightly concave, constricted at the sides and without a dorsal keel. The hind femora are shorter and the fore wings longer, the insects thus being more adapted for lengthy flights.

Intermediate between the solitary and gregarious phases is the *phasis transiens* which is to be regarded less as a definite phase than as a continuous series of intermediate forms. These occur either when the species is in process of transformation from the solitary to the gregarious phase, when the intermediate forms are termed *phasis transiens congregans,* or conversely when the gregarious phase is approaching its end and the species is reverting to the solitary phase, when they are termed *phasis transiens dissocians.* It should be realised that the change from the solitary to the gregarious phase and *vice versa* is not sudden, but may be spread over two or more generations of *phasis transiens.*

The principal factor that causes transition from *solitaria to gregaria, via* the intermediate *transiens congregans,* appears to be overcrowding, whether produced by laboratory experiments or, as in nature, by a combination of favourable ecological conditions resulting in an increase in the population of the solitary phase. It is probable that the greater activity induced by overcrowding produces the form of the thorax typical of *phasis gregaria,* while the characteristic pigmentation of the hoppers of this phase is the result of increased metabolic activity.

The practical importance of the phase theory is very great, for the areas where a species can live permanently in *phasis solitaria* until the ecological conditions become suitable for the production of *phasis gregaria* ("outbreak areas") appear to be limited in extent for each species. Provided therefore that these areas are known the way is open for altering these conditions or, if that is impossible, for control of the *phasis transiens congregans* before the production of migratory swarms.

Similar, though less well-marked, phase variability has been recorded by Rubtzov (6) in several non-migratory grasshoppers, the degree of variability in different species depending on the extent to which they can develop in large numbers in a restricted area, thus giving rise to overcrowding.

It has recently been shown that phase variation is not confined to the Acrididæ. Two South African entomologists (one of whom, J. C. Faure, was one of the first workers to prove experimentally Uvarov's original hypothesis) have demonstrated a comparable phenomenon in certain migratory Noctuid moths. The following account is mainly extracted from the summaries of their papers, or from the abstracts of them in the Review of Applied Entomology.

Faure (1) reared three generations of the Lesser Army Worm, *Laphygma exigua* (Hubn.), all under identical conditions except that 606 individuals were reared in isolation and 5764 in 39 crowds. Larvæ in or near the fifth instar were classified as phase *gregaria* (very dark in colour), *transiens* (dark grey) and *solitaria* (pale coloured). The average percentages of the total in each phase were 64.4, 27.3 and 8.3 for larvae reared in crowds and 0, 12 and 88 for those reared in isolation. The larvæ reared in crowds were far more active than the others : the activity probably led to the production of an excess of waste products, resulting in the formation of the black coloration. Adults from larvæ that developed in crowds were slightly darker on the forewings than those from larvæ kept in isolation, but the difference was not very striking, probably because excess waste products

are lost during the quiescent pupal stage. No differences were found in the size, wing length or other structural characters of the adults, or in the sharpness of the serrated edge of the mandibles of the exuviæ of fifth-stage larvæ.

Faure considered that if the parallel between phases in army worms and in locusts is valid for other aspects besides larval coloration, the former will also be able to live permanently in the phase *solitaria* only in comparatively small areas, within which swarms will develop when conditions are favourable for rapid multiplication, and from which the adults will migrate over long distances.

Faure (2) then made similar experiments with the Army Worm, *Laphygma exempta* (Walk.), and found that the larvæ developed phase variation to a more striking degree than those of *L. exigua*. He reared, over three generations, 12,385 larvæ in 34 crowds and all were classed as *gregaria* (dark colour) in their sixth instar. Of 909 reared in isolation, 1.1 per cent were classed as *gregaria*, 36.5 per cent as *transiens* (medium coloration) and 62.4 per cent as *solitaria* (light colour). Larvæ reared in crowds were much more active than isolated ones: they were much less inclined to cannibalism than those of *L. exigua*. Adults from crowded or isolated larvæ showed no difference in size, shape of wing or colour that could be correlated with phase variation, and no clear evidence was obtained of any physiological difference between the phases.

He adduced evidence that *L. exempta* does not breed permanently in the Union of South Africa, and this species has actually been observed in migration. He concludes that no real progress can be made in explaining the origin of serious outbreaks of *L. exempta* until its permanent breeding grounds and outbreak areas are discovered.

Matthée (4) continued Faure's work with *L. exempta* and confirmed the occurrence of phase variation. He found that it was possible to intensify the *solitaria* characteristics if the progeny of *solitaria* types were reared continuously in isolation. Phase characters were observable from the second instar larva onwards: *gregaria* show a higher percentage with black heads, and the width of the head is significantly less than in *solitaria* for every instar after the first. Nearly all the *solitaria* larvæ have five instars only, whereas probably all *gregaria* larvæ have six. Even in the sixth instar of *gregaria* the head is narrower than in the fifth instar of *solitaria*.

Matthée (5) also showed that similar phase variation occurs in another Noctuid, the Lawn Caterpillar, *Spodoptera abyssinia* Guén., the larva of which often causes serious damage to lawn grasses in South Africa. As with *L. exempta*, *solitaria* phase characters could be intensified by rearing continuously in isolation for three generations, but *gregaria* characters could not be intensified by continuous rearing in crowds.

In another publication Matthée (3) gives a detailed account of the biochemical differences found in the solitary and gregarious phases of two species of locusts (the African Migratory and the Brown Locust), *Laphygma exempta* and *Spodoptera abyssinia*.

He found that the lactic acid content was greater in the gregarious than in the solitary phase in the Noctuids, but not in the locusts. A possible explanation of the latter unexpected result might be that it was impossible to remove the normally inactive *solitaria* hoppers from their cages without causing them to jump about, and it is suggested that 30 seconds unaccustomed activity causes a rise in the lactic acid content of *solitaria* hoppers to the same level as that found in the normally active *gregaria* hoppers.

Uric acid was consistently more abundant in the solitary than in the gregarious phase of all four insects. This is an unexpected result for which no explanation is offered. Uric acid is the most important nitrogenous constituent in the excreta of insects and one would expect the difference in activity to cause a higher rate of metabolism in the gregarious phases; and that this would result in a higher total production of waste products. The fat content was significantly higher in *gregaria* than in *solitaria* in all the four species, probably due to the greater amount of food eaten by the more active phase.

Migration among insects is of much more frequent occurrence than is commonly supposed. Besides the locusts, there is a large number of butterflies that regularly migrate and a considerable number of moths, especially in the families Noctuidæ, Sphingidæ and Uraniidæ. There are also some migrant species of dragonflies. In addition to the armyworms mentioned above several of the migratory Lepidoptera are pests of some importance. For instance, the "cabbage white butterflies", *Ascia monuste* (L.) in the New world tropics and *Pieris brassicæ* L. in the Palæarctic region, are both pests of crucifers that frequently cause severe damage in places where they are not permanently resident. *A. monuste* invades Trinidad from the mainland almost every year, though not always in sufficient numbers to do much damage. The cotton worm, *Alabama argillacea* Hubn. is a serious pest of cotton in the southern States, the West Indies and South America. In many countries, e.g., the U.S.A., the Argentine and the West Indies, it seems unable to maintain itself permanently, but migrants arrive in greater or lesser numbers and after breeding for two or three generations die out completely until their next appearance. It probably originates in

Central America but the exact site of the outbreak areas is not yet known.

As yet there is no evidence that any of these other migratory insects exists in morphologically distinct solitary and gregarious phases. However, the work of Faure and Matthée outlined above suggests that this is at least a possibility and it is therefore quite conceivable that control of outbreaks of such pests as the cotton worm might be effected at the source, at a small fraction of the cost now entailed.

References

1. Faure, J. C. The Phases of the Lesser Army Worm. *Fmg. in S. Afr. 18,* pp. 69 — 78, 1943.
2. — — — — Phase variation in the Army Worm. *Sci. Bull. Dep. Agric. For. S. Afr.* No. 234, 1943.
3. Matthée, J. J. Biochemical Differences between the solitary and gregarious Phases of Locusts and Noctuids. *Bull. ent. Res. 36,* pp. 343 — 371, 1945.
4. — — — — A Study of the Phases of the Army Worm. *J. ent. Soc.* S. Afr. *9,* pp. 60 — 77, 1946.
5. — — — — Phase Variation in the Lawn Caterpillar. *Ibid. 10,* pp. 16 — 23, 1947.
6. Rubtzov, I. A. Phase variation in non-swarming Grasshoppers. *Bull. ent. Res. 26,* pp. 499 — 520, 1935.

T. W. K.

INITIAL SUCCESS OF ATTEMPTS AT THE BIOLOGICAL CONTROL OF THE WEED CORDIA MACROSTACHYA (JACQ.) R. AND S. IN MAURITIUS

By

F. J. Simmonds,

(Commonwealth Bureau of Biological Control)

About the beginning of this century a weed, *Cordia macrostachya,* was accidentally introduced from the West Indies to Mauritius in shipments of cane plants. Since that time the weed has spread considerably in the island becoming a major pest of pasture land, and giving considerable trouble in the sugar and fibre growing areas.

Eventually it was decided to attempt the biological control of the weed, and an investigation was begun in the West Indies (Wiehe 1946). Previous work was carried out by post-graduate students of the Imperial College of Tropical Agriculture, Trinidad, B.W.I. working under the direction of Professor A. M. Adamson and Dr. E. McC. Callan. Collections of insects feeding on *Cordia* in Trinidad were made and the life histories of several were investigated, including those of *Physonota alutacea* Boh., and *Schematiza cordiæ* Barb. (Kirby and Adamson 1944, Donald 1945).

Subsequently in 1946 the Commonwealth Bureau of Biological Control was requested to carry out further, more extensive investigations. The first species investigated were the leaf-eating beetles *Physonota* and *Schematiza* which had been worked on before. The biology of these species was investigated in detail and extensive feeding tests made. (Simmonds 1948, 1949 a,b,c,). Since they appeared to be highly specific in their food plants, completing their life cycles only on *Cordia macrostachya,* it was recommended that they be tried in Mauritius. Suitable methods of shipment were worked out and stocks of both species were successfully established, free naturally from their West Indian parasites, in the laboratory in Mauritius. Here further extensive feeding tests were made by Mr. J. R. Williams, Government Entomologist. It was at first suspected that *Schematiza* might under Mauritian conditions be able to develop on cabbages, but further experiments in both Trinidad and Mauritius indicated that it was only under very humid conditions in petri dishes in the laboratory that the larvæ would feed on cabbage, and that in the field this did not occur.

Physonota had been liberated at a number of points in the island, but in none did it appear to be becoming established, due, as was suggested from field work in Trinidad, to the depredations of ants on the eggs and young larvæ. This species has been found subsequently in one small ant-free area in Mauritius.

It was then decided to liberate *Schematiza.* Stocks were bred up in the laboratory in Mauritius, and between March 1948 and February 1949, approximately 18,000 adults were released in 18 localities covering widely different ecological conditions (Williams, unpublished reports). This was during the dry season in Mauritius and the beetles did not seem to thrive. In Trinidad during the dry season the species becomes largely inactive; very few larvæ can be found, and the adults are dormant in the debris below the *Cordia* bushes. However, with the onset of the rainy season in Mauritius in early 1949 " extremely large numbers " appeared in the field according to Mr. Williams. The following are quoted from his unpublished

reports as it was thought that this might be of some general interest. "Since the first liberation in March 1948 *Schematiza* has completely denuded many acres of *Cordia* of both leaves and inflorescences, while foliar damage, varying in its degree is more extensive . . . injury will be of very unequal intensity during any one year. The most severe damage will, however, coincide with the period of most vigorous growth of *Cordia*. *Schematiza* seems entirely suited to all the climatic regions where *Cordia* flourishes, while its great fecundity owing to its freedom from parasites ensures its rapid progress in coming years . . . damage to inflorescences has been almost as extensive as foliar injury. Wiehe (1946) estimated that one acre of *Cordia* scrub produces 134 million fruits a year . . . at the time of writing (June 1949) acres of scrub have been completely without inflorescences for five months owing to *Schematiza*."

The progress of *Schematiza* in controlling *Cordia* in Mauritius will be described later by Mr. Williams after further observations have been made in the next wet season, but it was felt that these preliminary results were of sufficient interest to justify recording immediately, even though it is impossible as yet to state the exact course of the populations of *Schematiza* in Mauritius nor the control of *Cordia* that will be achieved by this one species.

References

Wiehe, P. O. 1946 Report on a visit to Trinidad, Louisiana, and other countries. Dept. of Agric. Pub. No. 28, Mauritius, pp. 119.

Kirby, I. E. and Adamson, A. M. 1944 Insects on *Cordia* in Trinidad. Unpublished report. September, 1944.

Donald, R. G. 1945 The insects of "Black Sage" (*Cordia macrostachya*) in Trinidad. Unpublished thesis submitted in part requirement for the Associateship of the Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Simmonds, F. J. 1948 The effective control by parasites of *Schematiza cordiae* Barber in Trinidad. *Bull. Ent. Res.* 39, 2, 217—220.

Simmonds, F. J. 1949a. Insects attacking *Cordia macrostachya* (Jacq.) Roem. and Schult. in the West Indies I. *Physonota alutacea* Boh. (Coleoptera, Cassididae). In publication.

Simmonds, F. J. 1949b. Further effects of defoliation of *Cordia macrostachya* (Jacq.) R. and S. In publication.

Simmonds, F. J. 1950 Insects attacking *Cordia macrostachya* (Jacq.) Roem. and Schult. in the West Indies II. *Schematiza cordiae* Barb. (Coleoptera, Galerucidae). In publication.

Received for publication, July, 1949.

APPOINTMENT OF PROFESSOR OF AGRICULTURE

Applications for this appointment are invited.

The Department of Agriculture at the College is responsible for a major part of the teaching curriculum of the College.

A new 300 acre mixed farm is being developed besides other land for experimental purposes. There is ample opportunity for research and experimental work.

The salary of the post (including Allowances) is on a scale with a maximum of £1,890 a year. The point of entry of the successful applicant will be determined by age and experience.

A house is provided at a moderate rent. Superannuation under F.S.S.U. or other not less advantageous scheme. Long leave at the rate of four months every two years or six months every three years. Passages provided, and for wife and children up to 16, on appointment, leave and relinquishment of post. Free medical attention, and for wife and family, under specified conditions.

The man appointed will be required to assume duty not later than the beginning of the next Academic Year on 6th October, 1950.

Application forms and further particulars of the post can be obtained from the Secretary, Imperial College of Tropical Agriculture, 40 Norfolk Street, London, W.C.2., or from the Registrar, Imperial College of Tropical Agriculture, St. Augustine, Trinidad. B.W.I. Applications from suitably qualified men with wide experience of tropical agriculture should be sent to both of these addresses, and should be received not later than 31st March, 1950.

CITRUS EXPERT WANTED

WANTED For employment in Cyprus in a responsible Managing Capacity, on a large Agricultural Estate (about 2000 acres) planted mainly with Citrus and Sultana variety Vines, a qualified Citrus Expert with theoretical knowledge and practical experience. **Salary** £1000 per annum which includes cost of living bonus plus a commission on annual profits. Free accommodation on the Estate with lighting, car and use of telephone.

1st Class passage for applicant and family to Cyprus and return on termination of appointment. One year trial period with Company's option to extend for 3 to 4 years. Leave at the rate of 3 weeks per year.
Apply by Airmail giving qualifications, practical experience and curriculum vita together with full references to:

THE CYPRUS PALESTINE PLANTATIONS COMPANY LIMITED,

P.O.B. 180,

LIMASSOL, CYPRUS.